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# PROCEEDINGS

OF

# THE AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE.

NINTH MEETING,

HELD AT PROVIDENCE, R. I.,

AUGUST, 1855.

BOSTON MEDICAL
JUL 18 1892
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1856.

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EDITED BY

JOSEPH LOVERING,

*Permanent Secretary.*

CATALOGUED
JUL 18 1892
E. H. B.

CAMBRIDGE:
METCALF AND COMPANY, PRINTERS TO THE UNIVERSITY.

TO

THE

CITIZENS OF PROVIDENCE,

BY WHOSE HOSPITALITY THE ASSOCIATION WERE ENTERTAINED,

AND

TO WHOSE LIBERALITY THEY ARE INDEBTED FOR ASSISTANCE
IN THE MEANS OF PUBLICATION,

THIS VOLUME OF PROCEEDINGS

IS RESPECTFULLY INSCRIBED.

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## III. GEOLOGY.

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### V. PHYSIOLOGY.



## C. PRACTICAL SCIENCE.

### ENGINEERING.



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## EXECUTIVE PROCEEDINGS.

# OFFICERS OF THE ASSOCIATION

AT THE

# PROVIDENCE MEETING.

---

Prof. John Torrey, *President.*
Prof. Joseph Lovering, *Permanent Secretary.*
Prof. Wolcott Gibbs, *General Secretary.*
Dr. A. L. Elwyn, *Treasurer.*

*Standing Committee.*

Prof. John Torrey,
Prof. Joseph Lovering,
Prof. Wolcott Gibbs,
Dr. A. L. Elwyn,
Prof. J. D. Dana,
Prof. J. L. Smith,
Prof. A. D. Bache,
Prof. Alexis Caswell,
Zachariah Allen, Esq.,
Prof. James Robb,
Dr. B. A. Gould, Jr.,
William Mitchell, Esq.

*Local Committee.*

Prof. Alexis Caswell, *Chairman.*
W. F. Webster, *Secretary.*

Zachariah Allen,
Dr. J. Mauran,
Thomas P. Shepard,
Stephen T. Olney,
Owen Mason,
Prof. G. I. Chace,
George Thurber,
James Y. Smith,
Thomas Davis,
John Kingsbury,
Thomas L. Dunnell,
Amos D. Smith,
Walter Manton,
William P. Bullock,
Robert H. Ives,
William Goddard,

Thomas C. Hoppin,
William W. Hoppin,
Dr. J. Hartshorn,
Dr. Grosvenor,
P. Allen, Jr.,
John C. Brown,
Richard J. Arnold,
Henry B. Anthony,
Francis Wayland,
Jacob Dunnell,
Dr. S. B. Tobey,
Dr. I. Ray,
Samuel Ames,
John Gorham,
H. L. Kendall,
William W. Brown,
Stephen H. Smith,
Nicholas Brown,
William G. Angell,
Moses B. Ives,
Thomas J. Stead,
Isaac Thurber,
Rufus Waterman,
Richard Waterman,
George H. Corliss.

# SPECIAL COMMITTEES.

## A. Committees continued from Former Meetings.

*Committee to Memorialize the Legislature of Ohio on the Subject of a Geological Exploration of that State.*

Judge Lane, Sandusky, *Chairman.*
John Andrews, Esq., Columbus.
S. Medary, Esq., Columbus.
Judge Vance, Hamilton.
John H. James, Esq., Urbana.
Prof. S. St. John, Hudson.
Robert Buchanan, Esq., Cinc'ti.
John P. Foote, Esq., Cincinnati.
Hon. Allen Trimble, Highl'd Co.
Hon. S. J. Andrews, Cleveland.

*Committee to Revise the Constitution.*

Prof. A. D. Bache,
Prof. J. Lawrence Smith,
Prof. John Leconte,
Dr. Wolcott Gibbs,
Dr. B. A. Gould, Jr.,
Prof. W. B. Rogers,
Prof. J. D. Dana,
Dr. Joseph Leidy,
Prof. S. S. Haldeman,
Dr. A. A. Gould.

*Committee to Report in Relation to Uniform Standards in Weights, Measures, and Coinage.*

Prof. A. D. Bache,
Prof. Joseph Henry,
Prof. J. H. Alexander,
Prof. John F. Frazer,
Prof. Wolcott Gibbs,
Prof. Benjamin Peirce,
Prof. John Leconte,
Prof. W. B. Rogers,
Dr. J. H. Gibbon,
Dr. B. A. Gould, Jr.,
Prof. J. Lawrence Smith.

*Committee to Audit the Accounts of the Treasurer.*

Dr. Franklin Bache,
William S. Vaux, Esq.

## B. New Committees.

*Consulting Committee on the Publication of the Providence Proceedings.*

Prof. Benjamin Peirce,
Prof. Joseph Winlock,
Prof. Louis Agassiz,
Dr. Asa Gray.

*Consulting Committee on the Republication of the Cleveland Volume.*

Prof. Benjamin Peirce,
Prof. J. D. Dana,
Prof. Wolcott Gibbs,
Prof. A. D. Bache.

*Committee to Memorialize the Legislature of New York in Reference to Fish-Breeding.*

Prof. Louis Agassiz,
Prof. J. D. Dana.

# OFFICERS OF THE ALBANY MEETING.

---

Prof. James Hall, *President.*
Prof. Joseph Lovering, *Permanent Secretary.*
Dr. B. A. Gould, Jr., *General Secretary.*
Dr. A. L. Elwyn, *Treasurer.*

*Standing Committee.*

Prof. James Hall,
Prof. Joseph Lovering,
Dr. B. A. Gould, Jr.,
Dr. A. L. Elwyn,
Prof. John Torrey,
Prof. Wolcott Gibbs.

*Local Committee.*

Dr. T. R. Beck, *Chairman.*
Dr. James H. Armsby, *Secretary.*

Erastus Corning, Esq.,
Gideon Hawley, Esq.,
Thomas W. Olcott, Esq.,
Hon. D. D. Barnard,
Hon. A. J. Parker,
Ezra P. Prentice,
J. V. L. Pruyn, Esq.,
Dr. Thomas Hun.

# MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

| | Place. | Date. | President. | General Secretary. | Permanent Sec'y. | Treasurer. |
|---|---|---|---|---|---|---|
| 1st Meeting, | Philadelphia, Pa. | September 20, 1848, | W. C. Redfield, Esq., | Prof. Walter R. Johnson, | . . . | Prof. J. Wyman. |
| 2d " | Cambridge, Mass. | August 14, 1849, | Prof. Joseph Henry, | Prof. E. N. Horsford, | . . . | Dr. A. L. Elwyn. |
| 3d " | Charleston, S. C. | March 12, 1850, | Prof. A. D. Bache,* | Prof. L. R. Gibbes,* | . . . | Dr. St. J. Ravenel.* |
| 4th " | New Haven, Ct. | August 19, 1850, | Prof. A. D. Bache, | E. C. Herrick, Esq., | . . . | Dr. A. L. Elwyn. |
| 5th " | Cincinnati, Ohio, | May 5, 1851, | Prof. A. D. Bache, | Prof. W. B. Rogers, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 6th " | Albany, N. Y. | August 19, 1851, | Prof. L. Agassiz, | Prof. W. B. Rogers, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 7th " | Cleveland, Ohio, | July 28, 1853, | Prof. Benj. Peirce, | Prof. J. D. Dana, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 8th " | Washington, D. C. | April 26, 1854, | Prof. J. D. Dana, | Prof. J. Lawrence Smith, | Prof. J. Lovering, | Dr. J. L. Le Conte.* |
| 9th " | Providence, R. I. | August 15, 1855, | Prof. John Torrey, | Prof. Wolcott Gibbs, | Prof. J. Lovering, | Dr. A. L. Elwyn. |

* In the absence of the regular officer.

# CONSTITUTION OF THE ASSOCIATION.

## OBJECTS.

The Society shall be called "The American Association for the Advancement of Science." The objects of the Association are, by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of the United States; to give a stronger and more general impulse, and a more systematic direction, to scientific research in our country; and to procure for the labors of scientific men increased facilities and a wider usefulness.

## RULES.

### MEMBERS.

Rule 1. Those persons whose names have been already enrolled in the published proceedings of the Association, and all those who have been invited to attend the meetings, shall be considered members, on subscribing to these rules.

Rule 2. Members of scientific societies, or learned bodies, having in view any of the objects of this Society, and publishing transactions, shall likewise be considered members, on subscribing to these rules.

Rule 3. Collegiate professors of natural history, physics, chemistry, mathematics, and political economy, and of the theoretical and applied sciences generally, also civil engineers and architects who have been employed in the construction or superintendence of public works, may become members, on subscribing to these rules.

Rule 4. Persons not embraced in the above provisions may become members of the Association, upon nomination by the Standing Committee, and by a majority of the members present.

### OFFICERS.

Rule 5. The officers of the Association shall be a President, a Secretary, and a Treasurer; who shall be elected at each annual meeting, for the meeting of the ensuing year.

MEETINGS.

RULE 6. The Association shall meet annually, for one week or longer, the time and place of each meeting being determined by a vote of the Association at the previous meeting; and the arrangements for it shall be intrusted to the officers and the Local Committee.

STANDING COMMITTEE.

RULE 7. There shall be a Standing Committee, to consist of the President, Secretary, and Treasurer of the Association; the officers of the preceding year; the chairmen and secretaries of the Sections, after these shall have been organized; and six other members present, who shall have attended any of the previous meetings: to be elected by ballot.

RULE 8. The Committee, whose duty it shall be to manage the general business of the Association, shall sit during the meeting, and at any time in the interval between it and the next meeting, as the interests of the Association may require. It shall also be the duty of this Committee to nominate the general officers of the Association for the following year, and persons for admission to membership.

SECTIONS.

RULE 9. The Standing Committee shall organize the Society into Sections, permitting the number and scope of these Sections to vary in conformity to the wishes and the scientific business of the Association.

RULE 10. It shall be the duty of the Standing Committee, if, at any time, two or more Sections, induced by a deficiency of scientific communications, or by other means, request to be united into one, — or if at any time a single Section, overloaded with business, asks to be subdivided, — to effect the change, and generally to readjust the subdivisions of the Association, whenever, upon due representation, it promises to expedite the proceedings, and advance the purposes of the meeting.

SECTIONAL COMMITTEES AND OFFICERS.

RULE 11. Each Section shall appoint its own chairman and secretary of the meeting; and it shall likewise have a standing committee, of such size as the Section may prefer. The secretaries of the Sections may appoint assistants, whenever, in the discharge of their duties, it becomes expedient.

RULE 12. It shall be the duty of the standing committee of each Section, assisted by the chairman, to arrange and direct the proceed-

ings in their Section, to ascertain what written and oral communications are offered, and, for the better forwarding the business, to assign the order in which these communications shall appear, and the amount of time which each shall occupy; and it shall be the duty of the chairman to enforce these decisions of the committee.

These Sectional Committees shall likewise recommend subjects for systematic investigation, by members willing to undertake the researches, and present their results at the next annual meeting.

The committees shall likewise recommend reports on particular topics and departments of science, to be drawn up as occasion permits, by competent persons, and presented at subsequent annual meetings.

#### REPORTS OF PROCEEDINGS.

RULE 13. Whenever practicable, the proceedings shall be reported by professional reporters or stenographers, whose reports are to be revised by the secretaries before they appear in print.

#### PAPERS AND COMMUNICATIONS.

RULE 14. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declares such to be his wish before presenting it to the Society.

#### GENERAL AND EVENING MEETINGS.

RULE 15. At least three evenings of the week shall be reserved for general meetings of the Association, and the Standing Committee shall appoint these and any other general meetings which the objects and interests of the Association may call for.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Section; and thus all the Sections may, for a longer or shorter time, reunite themselves to hear and consider any communications, or transact any business.

It shall be a part of the business of these General Meetings to receive the Address of the President of the last Annual Meeting; to hear such reports on scientific subjects as, from their general importance and interest, the Standing Committee shall select; also to receive from the chairmen of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

RULE 16. The Association shall be organized by the President of the preceding Annual Meeting. The question of the most eligible distribution of the Society into Sections shall then occupy the attention of the Association; when, a sufficient expression of opinion being procured, the meeting may adjourn; and the Standing Committee shall immediately proceed to divide the Association into Sections, and to allot to the Sections their general places of meeting. The Sections may then organize by electing their officers, and proceed to transact scientific and other business.

LOCAL COMMITTEE.

RULE 17. The Standing Committee shall appoint a Local Committee from among members residing at or near the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements for the meeting.

SUBSCRIPTIONS.

RULE 18. The amount of the annual subscription of each member of the Association shall be two dollars; and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. The members attending an annual meeting shall pay, on registering their names, an additional assessment of ——— dollars. These subscriptions to be received by the Treasurer or Secretary.

RULE 19. The names of all persons two years and more in arrears for annual dues, shall be erased from the list of members: provided that two notices of indebtedness, at an interval of at least three months, shall have previously been given.

ACCOUNTS.

RULE 20. The accounts of the Association shall be audited annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 21. No article of this Constitution shall be altered or amended, without the concurrence of three fourths of the members present, nor unless notice of the proposed amendment or alteration shall have been given at the preceding annual meeting.

# RESOLUTIONS AND ENACTMENTS

## OF A PERMANENT AND PROSPECTIVE CHARACTER,

### PASSED PREVIOUS TO THE EIGHTH MEETING.

---

*Resolved*, That copies or abstracts of all communications made, either to the General Association or to the Sections, must be furnished by the authors; otherwise, only the titles shall appear in the published proceedings. (*Proceedings First Meeting*, 1848, p. 133.)

*Resolved*, That 1,000 copies of the Proceedings of the Association be published in pamphlet form, and placed at the disposal of the chairman of the Committee on Publication.

(*Proceedings First Meeting*, 1848, p. 133.)

*Resolved*, That a *manual* or *manuals of scientific observation and research*, especially adapted to the use of the American inquirer, comprising directions for properly observing phenomena in every department of physical science, and for making collections in natural history, etc., whether on land or at sea, is much needed at the present time; and that such a publication, placed in the hands of officers of the army and navy, would greatly tend to develop the natural resources of our extended country, and to the general advancement of science.

*Resolved*, That the American Association for the Advancement of Science cordially recommends the Smithsonian Institution to undertake the preparation of such a volume, under the editorial superintendence of its Secretary, to be published in its series of reports.

*Resolved*, That this Association will cordially co-operate in the production of such a manual or manuals, in whatever manner may be best adapted to secure the end in view.

(*Proceedings Second Meeting*, 1849, pp. 273, 351.)

*Resolved*, That no paper be read before the future meetings of the Association, unless an abstract of it has previously been presented to the Secretary.

*Resolved*, That hereafter all books, charts, maps, and specimens, which may be presented to the Association, shall be given to the Smithsonian Institution.

(*Proceedings Second Meeting*, 1849, p. 272.)

*Resolved*, That a Secretary be appointed, who shall hold his office for the term of three years, and shall have a salary of $300 per annum, and whose duty it shall be to compile for publication all proceedings or transactions of the Association, to superintend the publication of the same, and to conduct the correspondence; the title of said officer to be that of Permanent Secretary of the American Association. (*Proceedings Fourth Meeting*, 1850, p. 16.)

*Resolved*, That the Standing Committee have power to fix the duties of the Permanent Secretary of this Association.

*Resolved*, That the Permanent Secretary be a member, *ex officio*, of the Standing Committee.

*Resolved*, That the Permanent Secretary be instructed to erase from the list of members of this Association the names of all who, by the return of the Treasurer, shall appear to be two years in arrears for annual dues; suitable notice being given by two circulars from the Treasurer, at an interval of three months, to all who may fall within the intent of this resolution.

*Resolved*, That the Standing Committee have full power to complete and finish any outstanding business of the Association, in their name. (*Proceedings Fourth Meeting*, 1850, p. 341.)

*Resolved*, That a copy of the printed volume of Proceedings of the Meetings at Philadelphia, Cambridge, and New Haven be presented to the libraries of Harvard and Yale.

(*Proceedings Fourth Meeting*, 1850, p. 346.)

*Resolved*, That the Treasurer be requested to retain $300 of the funds in his hands, and belonging to the Association, for the purpose of paying the salary of the Permanent Secretary; said payment to be

made at such time, and in such manner, as may be agreed upon by the Treasurer and Permanent Secretary.

*Resolved*, That copies of the Proceedings of the American Association be presented to the New York Lyceum and the Philadelphia Academy of Natural Sciences.

*Resolved*, That the Permanent Secretary be requested to provide minute-books, suitably ruled, for the list of members and titles of papers, minutes of the general and sectional meetings, and for the other purposes indicated in the rules.

*Resolved*, That whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the Proceedings of the Association, that he be authorized to commit the same to the author, or to the proper sub-committee of the Standing Committee, for correction. (*Proceedings Fourth Meeting*, 1850, pp. 390, 391.)

*Resolved*, That copies of the Proceedings of the American Association for the Advancement of Science be presented to the American Academy of Arts and Sciences, Boston; to the Boston Society of Natural History; to the New York Lyceum of Natural History; to the American Philosophical Society and to the Academy of Natural Sciences of Philadelphia; to the Smithsonian Institution; and to the Western Academy of Natural Sciences at Cincinnati.

(*Proceedings Fifth Meeting*, 1851, p. 249.)

*Resolved*, That the Standing Committees of the Sections be requested, before the close of the meeting, to present to the Permanent Secretary a list of the papers which have been read in the Sections, and which they desire to have published.

*Resolved*, That hereafter all members of this Association are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

*Resolved*, That the foregoing resolution form part of the Circular.

(*Proceedings Sixth Meeting*, 1852, p. 402.)

*Resolved*, That the annual fee of membership be $2.00; and that payment of an additional dollar entitle a member to a copy of the Proceedings of the Meeting.

*Resolved*, That all members of the Association who have not paid their dues, after the issue of two circulars at intervals of three months, notifying them of that fact, be stricken from the roll by the Permanent Secretary.

(*Proceedings Sixth Meeting*, 1852, p. 402.)

Whereas the provision of the Constitution appears to be indefinite in regard to the term of service of the chairmen and secretaries of the Sections, —

*Resolved*, That the Sections be requested to direct the chairmen of their several Standing Committees to attend to the current business of the Section, and to appoint a chairman for each day of the meeting.

*Resolved*, That the Sections be requested to appoint a secretary for the period of the meeting, whose duty it shall be to furnish to the Permanent Secretary, for publication, a full report of all proceedings and discussions.

*Resolved*, That the following resolutions be presented to the Association at the opening of the Cleveland Meeting, for adoption: —

"1. That all papers, either at the general or in the several sectional meetings, shall be read in the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the Standing Committees of the Sections."

If this regulation shall be adopted by the Association, members will recognize the expediency of entering the titles of their communications at as early a date as possible.

"2. That, if any communication should not be ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

"3. That no exchanges shall be made between members, without authority of the respective Standing Committees."

(*Proceedings Sixth Meeting*, 1852, p. 405.)

*Resolved*, That the names of those only shall be entered in the list of members who shall have signified their acceptance.

(*Proceedings Seventh Meeting*, 1853.)

*Resolved*, That a sum not exceeding seventy-five dollars shall be paid to the Permanent Secretary, to defray the expenses necessary for attending each meeting of the Association.

(*Proceedings Seventh Meeting*, 1853.)

1st. *Resolved*, That priority of entry of a paper shall, as far as practicable, give precedence in its presentation; cases of exception to be decided by the Standing Committees of the Sections.

2d. *Resolved*, That, if any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

3d. *Resolved*, That no exchange shall be made between members without authority of the respective Standing Committees.

(*Proceedings Seventh Meeting*, 1853.)

---

*Resolved*, That the following members be requested to report on the subjects respectively assigned to them, viz.: —

PROF. A. D. BACHE. *On Recent Additions to our Knowledge of the Theory of Tides.*

PROF. JOSEPH HENRY. *On Recent Additions to our Knowledge of the Laws of Atmospheric Electricity.*

PROF. JAMES HALL. *On Recent Additions to our Knowledge of Paleozoic Rocks.*

PROF. J. L. SMITH. *On the Recent Progress of Micro-Chemistry.*

PROF. WOLCOTT GIBBS. *On the Recent Progress of Organic Chemistry.* (This report was made at the Providence Meeting.)

DR. JOSEPH LEIDY. *On the Remains of Fossil Reptiles and Mammals in North America.*

PROF. BENJAMIN PEIRCE. *On the Present State of the Theory of Planetary Perturbations.*

DR. W. I. BURNETT. *On Recent Advances in Anatomy and Physiology.*

PROF. LOUIS AGASSIZ. *On the History of our Knowledge of Alternation of Generation in Animals.*

PROF. J. D. DANA. *On the Geographical Distribution of the Lower Animals.*

PROF. L. S. HALDEMAN. *On the Present State of our Knowledge of Linguistic Ethnology.*

DR. B. A. GOULD, JR. *On the Progress and Developments of the Electro-Chronographic Method of Observation.*

(*Proceedings Seventh Meeting*, 1853.)

---

*Resolved*, That the Standing Committee be requested to print the existing Constitution, and the Constitution as proposed to be amended, and to distribute copies among the members of the Association.

(*Proceedings Eighth Meeting*, 1854.)

*Resolved*, That the Committee on the Constitution of the Association be continued, and requested to present for consideration at the next meeting a plan of By-Laws.

(*Proceedings Eighth Meeting*, 1854.)

# MEMBERS

OF THE

# AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE.

---

NOTE. — Names of deceased members are marked with an asterisk (*); and those of members who, in 1840, formed the original "Association of American Geologists," are in small capitals. The figure at the end of each name refers to the meeting at which the election took place.

## A.

Abbott, Gorham D., New York [7].
Abert, Col. J. J., Washington, D. C. [1].
*Adams, Prof. C. B., Amherst, Massachusetts [1].
Adamson, Rev. Wm., England [7].
Agassiz, Prof. Louis, Cambridge, Massachusetts [1].
Alexander, Dr. R. C., Bath, England [2].
Alexander, Prof. Stephen, Princeton, New Jersey [1].
Allen, Prof. E. A. H., New Bedford, Massachusetts [6].
Allen, George N., Oberlin, Ohio [5].
Allen, John H., Oxford, Maryland [6].
Allen, Zachariah, Esq., Providence [1].
Allston, R. F. W., Esq., Georgetown, South Carolina [3].
Allyn, Rev. Robert, E. Greenwich, Rhode Island [9].
*Ames, M. P., Esq., Springfield, Massachusetts [1].
Amory, Jonathan, Jamaica Plains, Massachusetts [8].
Andrews, Alonzo, Lewiston, Maine [7].

Andrews, E., M. D., Ann Arbor, Michigan [7].
Andrews, Prof. E. B., Marietta, Ohio [7].
Andrews, Prof. J. W., Marietta, Ohio [5].
Angell, Prof. James B., Providence [9].
Anthony, Charles H., Esq., Albany [6].
Anthony, Henry, Providence [9].
Anthony, J. G., Esq., Cincinnati, Ohio [1].
Appleton, Nathan, Esq., Boston [1].
Appleton, Thomas G., Boston [8].
Arden, Thomas B., Garrison's P. O., Putnam Co., New York [7].
Armsby, Prof. J. H., Albany [6].
Astrop, R. F., Crichton's Store, Burns Co., Virginia [7].
Austin, Samuel, Providence [9].
Ayres, William O., Esq., San Francisco, California [1].

B.

Bache, Prof. Alexander D., Washington, D. C. [1].
Bache, Dr. Franklin, Philadelphia [1].
Bacon, J. S., Pres., Washington, D. C. [1].
Bacon, Dr. John, Jr., Boston [1].
Bacon, William, Richmond, Berkshire Co., Massachusetts [7].
Baer, Prof. William, Sykesville, Maryland [8].
Bagg, Moses M., Utica, New York [4].
Bailey, Prof. J. W., West Point, New York [1].
Baird, Prof. S. F., Washington, D. C. [1].
Barlow, Thomas, Canastota, New York [7].
Barnard, F. A. P., Oxford, Mississippi [7].
Barnes, Capt. James, Springfield, Massachusetts [5].
Barratt, Dr. J. P., Barrattsville, South Carolina [3].
Bartlett, J. R., Providence [8].
Bartlett, Prof. W. H. C., West Point, New York [9].
Barton, Dr. E. H., New Orleans [9].
Bassnett, Thomas, Ottawa, Illinois [8].
Batchelder, J. M., Cambridge, Massachusetts [8].
Bean, Sidney A., Waukesha, Wisconsin [9].
Beck, Dr. C. F., Philadelphia [1].
*Beck, Prof. Lewis C., New Brunswick, New Jersey [1].
*Beck, Dr. T. Romeyn, Albany [1].

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Walker, Joseph (late U. S. A.), Platte City, Missouri [7].
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*Walker, Hon. Timothy, Cincinnati, Ohio [4].
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*Webster, M. H., Esq., Albany, New York [1].
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Webster, William F., Providence [9].
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Whitney, J. D., Esq., Northampton, Massachusetts [1].
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*Woodbury, Hon. L., Portsmouth, New Hampshire [1].
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Wormley, Theo. G., Columbus, Ohio [7].
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Wynne, Dr. James, Baltimore [8].

Wynne, Thomas H., Richmond, Virginia [8].

Y.

Yarnall, Prof. M., U. S. A. [8].
Youmans, E. L. Esq., Middlegrove, Saratoga Co., New York [6].
Young, Prof. Ira, Hanover, New Hampshire [7].

ADDENDUM.

Bouve, Thomas T., Esq., Boston [1].
Hammond, Ogden, Esq., Charleston [3].

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The above list contains six hundred and sixty-four names, of which fifty-nine are of deceased members.

# MEMBERS ELECTED AT THE PROVIDENCE MEETING.*

Alexander, Prof. J. H., Baltimore.
Allyn, Rev. Robert, E. Greenwich, R. I.
Angell, Prof. James B., Providence.
Anthony, Henry, Providence.
Austin, Samuel, Providence.
Bartlett, Prof. W. H. C., West Point, N. Y.
Barton, Dr. E. H., New Orleans.
Bean, Sidney A., Waukesha, Wisc.
Bigelow, Artemas, Newark, N. J.
*Borland, J. N., M. D., Boston.
Botta, Prof. Vincenzo, New York.
Brant, James R., New York.
Brooks, Charles, Boston.
Brown, John C., Providence.
Busher, James, Worcester, Mass.
Carr, E. S., Albany.
Cherriman, J. B., Toronto, Canada.
Clark, Bishop T. M., Providence.
Cleaveland, Prof. C. H., Cincinnati.
Clement, H. H., Providence.
Clum, H. A., Le Roy, N. Y.
Collins, Dr. George L., Providence.
*Cooper, William, Hoboken, N. J.
Corliss, George H., Providence.
Dakin, Prof. F. E., Troy, N. Y.
Davis, Prof. N. K., Marion, Alabama.
De Wolf, Prof. John, Bristol, R. I.
Dyer, Elisha, Providence.
Ely, Dr. J. W. C., Providence.
*Farmer, Moses G., Boston.
Fisher, Dr. N. A., Norwich, Conn.
Fisher, Robert A., Providence.
Francford, Dr. E., Middletown, Conn.
Goddard, William, Providence.
Green, Dr. John W., New York.
Greene, Samuel, Woonsocket, R. I.
Greene, Prof. Samuel S., Providence.
Greene, Thos. A., New Bedford, Mass.
Grosvenor, Dr. William, Providence.
Haines, William S., Providence.
Haven, Samuel F., Worcester, Mass.
Hazard, Rowland, Peace Dale, R. I.
Helme, W. H., Providence.
Holland, Joseph B., Monson, Mass.
Hollowell, W. E., Alabama.
Holton, J. F., New York.
Hunt, George, Providence.
Ives, Moses B., Providence.
Jones, Rev. George, U. S. N.
Loomis, L. Charles, Wilmington, Del.
Lockwood, Moses B., Providence.
Mahan, Prof. D. H., West Point, N. Y.
*Mason, Owen, Providence.
Mason, R. C., Appleton, Wisc.
Nason, Henry B., Worcester, Mass.

* This list also includes those who signed the Constitution, and paid the assessment, without being formally elected. Those marked with an asterisk paid the assessment, without signing the Constitution or being formally elected.

Okie, Abraham H., Providence.
Olney, Stephen T., Providence.
Ordway, John M., Roxbury, Mass.
Parsons, Dr. Charles H., Providence.
Parsons, Dr. Usher, Providence.
Peck, Lieut. G. W., U. S. T. E.
Peters, Dr. C. H. F., Cambridge, Mass.
Plumb, Dr. Ovid, Salisbury, Conn.
Ray, Dr. Isaac, Providence.
Richards, Rev. W. C., Providence.
Rodman, William M., Providence.
Ruggles, Samuel B., New York.
Savill, Henry M., Boston.
Shaw, Edward, Washington, D. C.
Shepard, Thomas P., Providence.
Smith, Prof. Francis H., Charlottesville, Va.
Smith, James Y., Providence.
Smith, Dr. Lyndon A., Newark, N. J.
Smith, Sanderson, New York.
Snow, E. M., Providence.
Stevens, Prof. M. C., Richmond, Ind.
Stone, Rev. Edwin M., Providence.
Suckley, Dr. George, U. S. A.
Tefft, Thomas A., Providence.
Thayer, Dr. S. W., Burlington, Vt.
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Tobey, Dr. Samuel B., Providence.
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Van Vleck, J. M., Middletown, Conn.
Vose, George B., New York.
Wagner, Tobias, Philadelphia.
Walling, Henry F., Providence.
Wayland, Francis P., Providence.
Webster, William F., Providence.
Williams, Dr. Abraham V., New York.
Wills, Frank, New York.
Wilson, George F., Providence.
Wright, Chauncey, Cambridge, Mass.

# ADDRESS

OF

PROFESSOR JAMES D. DANA,

AND

# REPORT

ON THE

RECENT PROGRESS OF ORGANIC CHEMISTRY,

BY

DR. WOLCOTT GIBBS.

BOSTON MEDICAL
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# ADDRESS

OF

# PROFESSOR JAMES D. DANA,

## PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE YEAR 1854,

### ON RETIRING FROM THE DUTIES OF PRESIDENT.

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Mr. President and Gentlemen of the American Association for the Advancement of Science: —

It is a noble object that invites us to these annual gatherings. Leaving the broils of the world to others, we come to contemplate together the teachings of God in nature. We come with faith in that word which is written around and within us, believing in the truthfulness of the revelation, and knowing that he who approaches it with an inquiring, teachable spirit, ever wakeful to the still, small voice, and forgetful of ambitious self, shall find the truth and feel its benign influence. We aim to decipher some new words in the volume of Nature, that we may learn the will of Him who has ordered all things well, and comprehend more fully His laws in the government of the universe.

In the use of this word *law*, as applied to nature, we are often grossly misunderstood. Says a recent writer, somewhat contemptuously, "The philosopher knows no better the cause of the law of gravitation than the ignorant man." The author, in his simplicity, is unaware that laws, not causes, are the end of true philosophy. We seek to study out the method of God's doings in nature, and enunciations of this

his method or will are what is meant by the "laws of nature." If those who look coldly on science knew better its aims, we should hear less of the infidelity of the term *law*, and find fewer infidels or rejecters of that revelation which God has spread out before us.

We know that this is not the only revelation; that another tells man of his duties and responsibilities, of the celestial sympathy which surrounds him, and his immortal destiny,— subjects far beyond the teachings of physical or brute nature. The one is but the complement of the other; the two harmonious in their truths, as in their exalted origin.

Although different in scope, they teach alike humility and reverence. To the vision of science, there is nothing in nature minute or unworthy. It pities the feeling that would turn with contempt from the meanest created thing. For it stops not with mere externals, but distinguishes profound relations and universal laws beneath the surface. Exhibit the leaf of a plant, or an animalcule, under a microscope, to a person of good taste, as the phrase is, and he will appreciate the beautiful coloring and the wonderful forms displayed; for form and color are media of real beauty in nature, and there are eyes enough to admire. But let another look whose mind has been deeply imbued with science, and profounder beauties open to his view; the object is not an isolated thing of exquisite tints or admirable shape; it takes its place in the vast system of nature, and derives grandeur beyond estimate from its relations to that system. Nature becomes a living expression — as full as is possible in finite language — of the perfections of the Supreme Architect, with whom to create has ever been to evolve beauty amid displays of wisdom and beneficence. And the devout mind finds deeper meaning in the words Reverence and Humility, and ceaseless promptings to his Gratitude and Love.

We have reason for gratulation that correct views respecting Natural and Physical Science are rapidly becoming general throughout our land. Among its votaries, while

every new fact is heartily welcomed to its place, there is a strong distaste for human fancies as a substitute for divine truths, or for theories without a broad basis of ascertained facts. Moreover, there is, at large, an appreciation of the value of science, not merely for its baser purpose of turning everything into gold, but for its nobler end of opening the earlier revelation. The means also for the prosecution of science are gradually extending, and it is favorably recognized, with hardly an exception, in all the literary institutions of the country, though not generally raised to that honorable place which it may expect in the future.

Happily, too, there is much to encourage extended research in the opportunities now before us for the publication of elaborate original memoirs. Not, indeed, in the small treasury of this Association, which boasts more of the mutual good-will and the ideas it elicits than of its moneyed resources, but in the transactions of different scientific societies or academies and the periodical press, and pre-eminently in the Smithsonian Institution, through the munificence of Smithson, who gave his fortune expressly for this end, — the *increase* and *diffusion* of knowledge among men. It has been recently attempted to strike out the *idea*, if not the *word increase*, and, in equal wisdom, it was thought to *diffuse knowledge* over this extended territory and the world by stationing a collection of books at Washington. Fortunately for knowledge and the country such counsels have not prevailed. The funds for publication and for its other legitimate purposes are, in fact, lamentably small. An annual income of thirty-one thousand dollars, diminished one third by the incidental expenses of the Institution, is a meagre allowance. The complete elaboration and publication yearly of the meteorological results, from the facts now constantly coming in, would alone require half the available publication fund; and, on account of its expense, has not yet been attempted. And what shall be said of other departments, and the costly illustrations which detailed investigations require? It is well the country

has what it has. It would be vastly more for its interests, and for the increase and diffusion of knowledge among men, if the resources for publication were tenfold larger.

In selecting a topic for this occasion, I have not been without perplexity. Before an Association for the Advancement of Science, — science in its wide range, — a discourse on the progress of science in America for the past year would seem legitimate. Yet it is a fact that the original memoirs in most departments, published within that period, would make a very meagre list. Moreover, it is too much to expect of any one to roam over other's territories, lest he ignorantly gather for you noxious weeds. I have, therefore, chosen to confine myself to a single topic, that of Geology; and I propose, instead of simply reviewing recent geological papers, to restrict myself to some of the general conclusions that flow from the researches of American geologists, and the bearing of the facts or conclusions on geological science. I shall touch briefly on the several topics, as it is a subject that would more easily be brought into the compass of six hours than one. In drawing conclusions among conflicting opinions, or on points where no opinion has been expressed, I shall endeavor to treat the subject and the views of others in all fairness, and shall be satisfied if those who differ from me shall acknowledge that I have honestly sought the truth.

In the first place, we should have a clear apprehension of the intent or aim of Geological Science. It has been often said, that Geology is a *history*, the records of which are written in the rocks; and such is its highest department. But is this clearly appreciated? If so, why do we find text-books, even the one highest in authority in the English language, written back end foremost, — like a History of England commencing with the reign of Victoria. In history, the phases of every age are deeply rooted in the preceding, and intimately dependent on the whole past. There is a literal unfolding of events as time moves on, and this is eminently true of Geology.

Geology is not simply the science of rocks, for rocks are but incidents in the earth's history, and may or may not have been the same in distant places. It has its more exalted end, — even the study of the progress of life from its earliest dawn to the appearance of man; and instead of saying that fossils are of use to determine rocks, we should rather say that the rocks are of use for the display of the succession of fossils. Both statements are correct; but the latter is the fundamental truth in the science.

From the progress of life, geological time derives its division into Ages, as has been so beautifully exhibited by Agassiz. The successive phases in the progress of life are the great steps in the earth's history. What if in one country the rocks make a consecutive series without any marked interruption between two of these great ages, while there is a break or convenient starting-point in another; does this alter the actuality of the ages? It is only like a book without chapters in one case, and with arbitrary sections in another. Again, what if the events characteristic of an age — that is, in Geology, the races of plants or animals — appear to some extent in the preceding and following ages, so that they thus blend with one another? It is but an illustration of the principle just stated, that *time is one.* Ages have their progressive development, flowing partly out of earlier time, and casting their lights and shadows into the far future. We distinguish the ages by the culmination of their great characteristics, as we would mark a wave by its crest.

Divisions of time *subordinate* to the great ages will necessarily depend on revolutions in the earth's surface, marked by abrupt transitions either in the organic remains of the region, or in the succession of rocks. Such divisions are not universal. Each continent has its own periods and epochs, and the geologists of New York and other States have wisely recognized this fact, disregarding European *stages* or subdivisions. This is as true a principle for the Cretaceous and Tertiary, as for the Silurian and Devonian. The usurpation of Cromwell

made an epoch in English annals; not in the French or Chinese. We should study most carefully the records, before admitting that any physical event in America was contemporaneous with a similar one in Europe. The unity in geological history is in the progess of life and in the great physical causes of change, not in the succession of rocks.

The geological ages, as laid down by Agassiz, are the following:— I. The Age of Fishes, including the Silurian and Devonian; II. The Age of Reptiles, embracing from the Carboniferous through the Cretaceous; III. The Age of Mammals, the Tertiary and Post-tertiary; IV. The Age of Man, or the recent era;—*fishes* being regarded as the highest and characteristic race of the first age; *reptiles* of the second; and *mammals* of the third.

More recent researches abroad, and also the investigations of Mr. Hall in this country, have shown that the supposed Fish remains of the Silurian are probably fragments of Crustacea, if we except those of certain beds near the top of the Silurian; and hence the *Age of Fishes* properly begins with the Devonian. What then is the Silurian? It is pre-eminently the Age of Mollusks.

Unlike the other two Invertebrate sub-kingdoms, the *Radiate* and *Articulate*, which also appear in the earliest fossiliferous beds, the *Molluscan* sub-kingdom is brought out in all its grander divisions. There is not simply the type, but the type analyzed or unfolded into its several departments, from the Brachiopods and Bryozoa up to the highest group of all, the Cephalopods. And among these Cephalopods, although they may have been inferior in grade to some of later periods, there were species of gigantic size, the shell reaching a length of ten or twelve feet. The Silurian is therefore most appropriately styled the *Molluscan Age*.

The Palæozoic Trilobites were the lowest among Crustacea, and Crustacea rank low among Articulates. Moreover, Crustacea (and the Articulata in general) did not reach their fullest development until the Human Era.

The Radiata were well represented in the Silurian periods; but, while inferior to the Mollusca as a sub-kingdom, only corals and crinoids, the lower fixed or vegetative species, with rare exceptions, occur in the Silurian or Molluscan Age.

The Articulata and Radiata thus begin early, but with only the lower forms in each, and neither is a leading class in any age.

Viewing the history, then, *zoölogically*, the ages are — the Age of Mollusks, of Fishes, of Reptiles, of Mammals, of Man.

We may now change the point of view to the Vegetable Kingdom. The ages thence indicated would be three: —

I. The *Age of Algæ*, or marine plants, corresponding to the Silurian and Devonian.

II. The *Age of Acrogens*, or flowerless trees, that is, the Lepidodendra, Sigillariæ, and Calamites, — corresponding to the Coal Period and Permian; — a name first proposed by Brongniart, and which may still be retained, as it is far from certain that the Sigillariæ and Calamites are most nearly related to the Coniferæ.

III. The *Age of Angiosperms*, or our common trees, like the Oak, Elm, &c., beginning with the Tertiary.

The interval between the second and third of these ages is occupied mainly by Coniferæ, the Pine tribe, and Cycadeæ, the true Gymnosperms, species of which were abundant in the Coal Period, and have continued common ever since. The Coniferæ, in the simplicity of their flowers and their naked seeds, are next akin to the Acrogens or flowerless trees. Although in the main a flowerless vegetation, for the few supposed remains of flowers observed abroad have been recently referred to undeveloped leaf-buds, it appears probable from the observations of Dr. Newberry, that there were some true flowers over the Ohio prairies, — apparently monocotyledonous, and related to the Lily tribe. But no traces of Palms or monocotyledonous trees have been found in the coal-fields of this country.

Combining the results from the animal and vegetable king-

doms, we should introduce the Age of Acrogens, for the Coal Period and Permian, between the Age of Fishes and Age of Reptiles, — a space in time zoölogically occupied by the overlapping of these two ages.

The order then reads, the Age of MOLLUSKS, of FISHES, of ACROGENS or coal plants, of REPTILES, of MAMMALS, of MAN.

The limits of these ages are as distinct as history admits of; their blendings where they join, and the incipient appearance of a type before the age it afterwards characterizes fully opens, are in accordance with principles already explained.

The reality of progress from lower to higher forms is not more strongly marked in these names, properly applied, than in the rocks. If, hereafter, mammals, reptiles, or fishes are found a little lower than now known, it will be changing but a sentence in the history, — not the grand idea which pervades it.

A theory lately broached by one whose recent death has caused universal grief to science, supposes that the Reptilian was an age of diminished life, between the two extremes in time, the Palæozoic and Mammalian Ages. But, in fact, two grand divisions of animals, the Molluscan and Reptilian, at this time reach their climax and begin their decline, and this is the earliest instance of the highest culmination of a grand zoölogical type.

Preceding the Silurian or Molluscan Age, there is the AZOIC AGE, or *age without animal life*. It was so named by Murchison and De Verneuil, and first recognized in its full importance, and formally announced, in this country, in the Geological Report of Messrs. Foster and Whitney, although previously admitted, in an indefinite way, by most geologists.

It embraces all the lowest rocks, up to the Silurian, for much of the lowest granite cannot be excluded.

The actual absence of animal life in the so-called Azoic Age in this country is rendered highly probable, as Foster and Whitney show, by the fact that many of the rocks are slates and sandstones, like fossiliferous Silurian rocks, and yet have

no fossils; and moreover, the beds on this continent were uplifted and folded, and, to a great extent, crystallized, on a vast scale, before the first Silurian layers were deposited. A grand revolution is here indicated, apparently the closing event of the early physical history of the globe.

As plants may live in water too hot or impure for animals, and moreover, since all nature exemplifies the principle that the earth's surface was occupied with life as soon as fitted, and with the highest forms the conditions of the time allowed, we may reasonably infer that there may have been in Azoic times marine species and plant-infusoria, forms adapted to aid in the earth's physical history; and thus *vegetation* may have long preceded animal life on the globe.

After these general remarks on the divisions of Geological time, I now propose to take up the characteristic features and succession of events in American Geology.

In the outset we are struck with the comparative simplicity of the North American continent, both in form and structure. In *outline* it is a triangle, the simplest of mathematical figures; in *surface*, it is only a vast plain lying between two *mountain* ranges, one on either border, the Appalachian from Labrador to Alabama on the east, the Rocky Mountains on the west; and on its *contour* it has water, east, west, north, and south.

Observe too that its border heights are proportioned to the size of the oceans. A *lofty* chain borders the Pacific, a *low* one the narrow Atlantic, while the small Arctic is faced by no proper mountain range.

This principle, that the highest mountains of the continents face the largest oceans, is of wide application, and unlocks many mysteries in Physical Geography. South America lies between the same oceans as North America; it has its eastern low range, its western Andes; and as the oceans widen southward, the continent is there pinched up almost to a narrow mountain ridge. It differs from North America in having a large expanse of ocean, the Atlantic, on the north,

and, correspondingly, it has its northern mountain ridge. The world is full of such illustrations, but I pass them by.

This simplicity of ocean boundary, of surface features, and of outline, accounts for the simplicity of geological structure in North America; or we may make the wider statement, that all these qualities are some way connected with the positions and extent of the oceans, they seeming to point to the principle, that the subsidence of the oceanic basins had determined the continental features; and that both results were involved in the earth's gradual refrigeration, and consequent contraction.

America has thus the simplicity of a single evolved result. Europe, on the contrary, is a world of complexities. It is but one corner of the Oriental continent, which includes Europe, Asia, and Africa, and while the ocean bounds it on the north and west, continental lands inclose it on the south and east. It has ever been full of cross purposes. American strata often stretch from the Atlantic west beyond the Mississippi; and east of the Rocky Mountains, it has but one proper mountain range of later date than the Silurian. Europe is much broken up into basins, and has mountains of all ages: even the Alps and Pyrenees are as recent as the Tertiary.

This wide contrast accounts for the greater completeness or generality of American revolutions, the more abrupt limits of periods, and clearer exhibition of many geological principles.

The geological structure of this country has been made known through the combined researches of a large number of investigators. The names of MACLURE, SILLIMAN, EATON, lead off the roll; HITCHCOCK, the Professors ROGERS, the well-known GEOLOGISTS OF THE NEW YORK SURVEY, OWEN, PERCIVAL, MORTON, CONRAD, TUOMEY, and many others, have made large contributions to the accumulating results. Yet the *system* may be said to have been mainly laid open by four sets of observers, — MORTON for the Cretaceous; CONRAD for the Tertiary; the NEW YORK GEOLOGISTS for the Palæo-

zoic strata; and the Professors ROGERS for the Carboniferous beds and the Appalachians.

The succession of Silurian and Devonian rocks in the State of New York is the most complete in the country, and it was well for the science that its rocks were so early studied, and with such exactness of detail. The final display of the Palæontology by Mr. James Hall has given great precision to the facts, and the system has thereby become a standard of comparison for the whole country, and even for the world.

This accomplished, the carboniferous rocks were still to be registered, and the grand problem of New England Geology solved. The Professors Rogers, in the surveys of Pennsylvania and Virginia, followed out the succession of strata from the Devonian through the Coal Period, and thus, in a general way, completed the series. And more than this, they unravelled with consummate skill the contortions among the Appalachians, bringing order out of confusion, and elucidating a principle of mountain-making which is almost universal in its application. They showed that the Silurian, Devonian, and Carboniferous strata, which were originally laid out in horizontal layers, were afterwards pressed on to the northwestward, and folded up till the folds were of mountain height, and that thus the Appalachians had their origin; and also that, by the escaping heat of those times of revolution, extensive strata were altered, or even crystallized.

This key soon opened to us a knowledge of New England Geology, mainly through the labors of Mr. Hall, and also of Professor H. D. Rogers, following up the survey of President Hitchcock; and now these so-called primary rocks, granite, gneiss, schists, and crystalline limestones, once regarded as the oldest crystallizations of a cooling globe, are confidently set down as for the most part no older than the Silurian, Devonian, and Carboniferous of New York and Pennsylvania.

Let us now briefly review the succession of epochs in American geological history.

The Azoic Age ended, as was observed, in a period of ex-

tensive metamorphic action and disturbance, — in other words, in a vast revolution. At its close, some parts of the continent were left as dry land, which appear to have remained so, as a general thing, in after times; for no subsequent strata cover them. Such are a region in Northern New York, others about and beyond Lake Superior, and a large territory across the continent from Labrador westward, as recognized by Messrs. Whitney and Hall, and the geologists of Canada.

The Silurian or Molluscan Age next opens. The lowest rock is a sandstone, one of the most widely spread rocks of the continent, stretching from New England and Canada south and west, and reaching beyond the Mississippi, — how far is not known. And this first leaf in the record of life is like a title-page to the whole volume, long afterwards completed; for the nature of the history is here declared in a few comprehensive enunciations.

1. The rock, from its thin, even layers, and very great extent, shows the wide action of the ocean in distributing and working over the sands of which it was made; and the ocean ever afterwards was the most active agency in rock-making.

2. Moreover, ripple-marks, such as are made on our present sea-shores or in shallow waters, abound in the rock, both through the east and west, and there are other evidences also of moderate depths, and of emerged land; they all announce the wonderful fact, that even then, in that early day, when life first began to light up the globe, the continent had its existence: — not in embryo, but of full-grown extent; and the whole future record is but a working upon the same basis, and essentially within the same limits. It is true that but little of it was above the sea, but equally true that little of it was at great depths in the ocean.

3. Again, in the remains of life which appear in the earliest layers of this primal rock, three of the four great branches of the Animal Kingdom are represented, — Mollusks, Trilobites among Articulates, and Corals and Crinoids among Radi-

ates, — a sufficient representation of life for a title-page. The New York beds of this rock had afforded only a few Mollusks; but the investigations of Owen in Wisconsin have added the other tribes; and this diversity of forms is confirmed by Barrande in his Bohemian researches.

Among the genera, while the most of them were ancient forms that afterwards became extinct, and through succeeding ages thousands of other genera appeared and disappeared, the very earliest and most universal was one that now exists, — the genus *Lingula*, — thus connecting the extremes of time, and declaring most impressively the unity of creation. Mr. T. S. Hunt, of the Canada Geological Survey, recently discovered that the ancient shell had the anomalous chemical constitution of bones, being mainly phosphate of lime; and afterwards he found in a modern Lingula the very same composition, — a further announcement of the harmony between the earliest and latest events in geological history.

This earliest sandstone, — called in New York the Potsdam sandstone, — and the associate Calciferous Sand-rock, mark off the *First Period* of the Molluscan Age, — the POTSDAM PERIOD, as it may be called.

Next followed the TRENTON PERIOD, — a period of limestones, (the Trenton limestone among them,) equal to the earlier beds in geographical limits, and far more abundant in life, for some beds are literally shells and corals packed down in bulk: yet the species were new to the period, the former life having passed away; and even before the Trenton Period closed, there were one or two epochs of destruction of life followed by new creations. The formation of these limestone beds indicates an increase in the depth of the continental seas, — an instance of the oscillation of level to which the earth's crust was almost unceasingly subject through all geological ages until the present.

After the Trenton Period, another change came over the continent, and clayey rocks or shales were formed in thick deposits in New York, and south, — the Utica slate and Hud-

son River shales, — while limestones were continued in the West. This is the Hudson Period; and with it, the *Lower Silurian* closed.

The seas were then swept of their life again, and an abrupt transition took place both in species and rocks. A conglomerate covered a large part of New York and the States south, its coarse material evidence of an epoch of violence and catastrophe: and with this deposit the *Upper Silurian* began.

The Upper Silurian had also its three great periods, — the Niagara, the Onondaga, and the Lower Helderberg, besides many subordinate epochs, — each characterized by its peculiar organic remains, — each evidence of the nearly or quite universal devastation that preceded it, and of the act of omnipotence that reinstated life on the globe, — each, too, bearing evidence of shallow or only moderately deep waters when they were formed; and the Onondaga Period — the period of the New York salt rocks — telling of a half-emerged continent of considerable extent.

Another devastation took place, and then opened, as De Verneuil has shown, the Devonian Age, or *Age of Fishes.* It commenced, like the Upper Silurian, with coarse sandstones, evidence of a time of violence; these were followed by another grit rock, whose few organic remains show that life had already reappeared. Then another change, — a change evidently in depth of water, — and limestones were forming over the continent, from the Hudson far westward: the whole surface became an exuberant coral reef, far exceeding in extent, if not in brilliancy, any modern coral sea; for such was a portion, at least, of the Upper Helderberg Period.

Again there was a general devastation, leaving not a trace of the former life in the wide seas; and where were coral reefs, especially in the more eastern portion of the continental seas, sandstones and shales accumulated for thousands of feet in thickness, with rarely a thin layer of limestone. Thus passed the Hamilton, Chemung, and Catskill Periods, of the Devonian age. The life of these regions, which in some

epochs was exceedingly profuse, was three or four times destroyed and renewed: — not renewed by a re-creation of the same species, but by others; and although mostly like the earlier in genera, yet each having characteristic marks of the period to which it belonged. And while these Devonian Periods were passing, the first land plants appeared, foretellers of the Age of Verdure, next to follow.

Then come vast beds of conglomerate, a natural opening of a new chapter in the record; and here it is convenient to place the beginning of the Carboniferous Age, or the Age of ACROGENS. Sandstones and shales succeeded, reaching a thickness, in Pennsylvania and New Jersey, according to Professor Rogers, of thousands of feet; while in the basin of the Ohio and Mississippi, in the course of this era, the Carboniferous limestone was forming from immense crinoidal plantations in the seas.

Another extermination took place of all the beautiful life of the waters, and a conglomerate or sandstone was spread over the encrinital bed: and this introduced the true coal period of the Carboniferous Age; — for it ended in leaving the continent, which had been in long-continued oscillations, quite emerged. Over the regions where encrinites were blooming, stretch out vast prairies or wet meadows of the luxuriant coal vegetation. The old system of oscillations of the surface still continues, and many times the continent sinks to rise again, — in the sinking, extinguishing all continental life, and exposing the surface to new depositions of sandstone, clays, or limestone over the accumulated vegetable remains; in the rise, depopulating the seas by drying them up, and preparing the soil for verdure again, or at times convulsive movements of the crust carry the seas over the land, leaving destruction behind: and thus by repeated alternations the coal period passes, some six thousand feet of rock and coal-beds being formed in Pennsylvania, and fourteen thousand feet in Nova Scotia.

I have passed on in rapid review, in order to draw attention

to the series or succession of changes, instead of details. So brief an outline may lead a mind not familiar with the subject to regard the elapsed time as short; whereas to one who follows out the various alternations and the whole order of events, the idea of *time immeasurable* becomes almost oppressive.

Before continuing the review, I will mention some conclusions which are here suggested.

I. In the first place, through the periods of the Silurian and Devonian, at twelve distinct epochs, at least, the seas over this American continent were swept of all, or nearly all, existing life, and as many times it was repeopled: and this is independent of many partial exterminations and renewals of life that at other times occurred.

If Omnipotent Power had been limited to making *monads* for after development into higher forms, many a time would the whole process have been utterly frustrated by hot water, or by mere changes of level in the earth's crust, and creation would have been at the mercy of dead forces. The surface would have required again and again the sowing of monads, and there would have been a total failure of crops after all; for these exterminations continue to occur through all geological time into the Mammalian Age.

II. Again: I have observed that the continent of North America has never been the deep ocean's bed, but a region of comparatively shallow seas, and at times emerging land; and was marked out in its great outlines even in the earliest Silurian. The same view is urged by De Verneuil, and appears now to be the prevailing opinion among American geologists. The depth at times may have been measured by the thousand feet, but not by miles.

III. During the first half of the lower Silurian era, the whole east and west were alike in being covered with the sea. In the first or Potsdam Period, the continent was just beneath its surface. In the next or Trenton Period, the depth was greater, giving purer waters for abundant marine life. After-

wards, the East and West were in general widely diverse in their formations; limestones, as Mr. Hall and the Professors Rogers have remarked, were in progress over the West, that is, the region, now the great Mississippi Valley, beyond the Appalachians, while sandstones and shales were forming, from Northeastern New York, south and southwest through Virginia. The former, therefore, has been regarded as an area of deeper waters, the latter as, in general, shallow, when not actually emerged. In fact, the region towards the Atlantic border, afterwards raised into the Appalachians, was already, even before the Lower Silurian era closed, the higher part of the *land*: it lay as a great reef or sand-bank, partly hemming in a vast continental lagoon where corals, encrinites, and mollusks grew in profusion, thus separating more or less perfectly the already existing Atlantic from the interior waters.

IV. The oscillations or changes of level over the continent, through the Upper Silurian and Devonian, had some reference to this border region of the continent: the formations approach or recede from it, and sometimes pass it, according to the limits of the oscillation eastward or westward. Along the course of the border itself there were deep subsidences in slow progress, as is shown by the thickness of the beds. It would require much detail to illustrate these points, and I leave them with this bare mention.

The Hudson River and Champlain valleys appear to have had their incipient origin at the epoch that closed the Lower Silurian; for while the preceding formations cross this region and continue over New England, the rocks of the Niagara and Onondaga Periods (the first two of the Upper Silurian) thin out in New York before reaching the Hudson River. Mr. Logan has recognized the division of America to the northeast into two basins by an anticlinal axis along Lake Champlain, and observes also that the disturbances began as early, at least, as the close of the Lower Silurian, mentioning, too, that there is actually a want of conformity at Gaspé between the beds of the Upper and Lower Silurian, —

another proof of the violence that closed the Lower Silurian era.

But let us pass onward in our geological record.

All the various oscillations that were in slow movement through the Silurian, Devonian, and Carboniferous Ages, and which were increasing their frequency throughout the last, raising and dipping the land in many alternations, were premonitions of the great period of revolution, — so well elucidated, as already observed, by the Professors Rogers, — when the Atlantic border, from Labrador to Alabama, long in preparation, was at last folded up into mountains, and the Silurian, Devonian, and Carboniferous rocks were baked or crystallized. No such event had happened since the revolution closing the Azoic Period. From that time on, all the various beds of succeeding ages up to the top of the Carboniferous had been laid down in horizontal or nearly horizontal layers, over New England as well as in the West, — for the continent from New England westward, we have reason to believe, was then nearly a plain, either above or below the water; there had been no disturbances except some minor uplifts: the deposits, with small exceptions, were a single unbroken record, until this Appalachian revolution.

This epoch, although a time of vast disturbances, is more correctly contemplated as an epoch of the slow measured movement of an agency of inconceivable power, pressing forward from the ocean towards the northwest; for the rocks were folded up without the chaotic destruction that sudden violence would have been likely to produce. Its greatest force and its earliest beginning was to the northeast. I have alluded to the disturbance between the Upper and Lower Silurian beds of Gaspé, to the north: another epoch of disturbance, still more marked, preceded, according to Mr. Logan, the Carboniferous beds in those northeastern regions; and New England, while a witness to the profound character and thoroughness of the Appalachian revolution, attests also to the greater disturbance towards its northern limits. Some

of the Carboniferous strata were laid down here in Rhode Island, as clay and sand and layers of vegetable *débris:* they came forth from the Appalachian fires as you now have them, the beds contorted, the coal layers, a hard siliceous anthracite or even graphite in places, the argillaceous sands and clays, crystallized as talcose schist, or perhaps gneiss or syenite.

These very coal-beds, so involved in the crystalline rocks, are part of the proof that the crystallization of New England took place after the Coal Era. Fossils in Maine and Massachusetts add to the evidence; the quiet required by the continent for the regular succession and undisturbed condition of the rocks of the Silurian, Devonian, and Carboniferous formations, shows that in neither of these ages could such vast results of metamorphic action and upheaval have taken place.

The length of time occupied by this revolution is beyond all estimate. Every vestige of the ancient Carboniferous life of the continent disappeared before it. In Europe, a Permian Period passed, with its varied life; yet America, if we may trust negative evidence, still remained desolate. The Triassic Period next had its profusion of living beings in Europe, and over two thousand feet of rock; America through all, or till its later portions, was still a blank: not till near the beginning of the Jurassic Period do we find any traces of new life, or even of another rock above the Carboniferous.

What better evidence could we have than the history of the oscillations of the surface, from the earliest Silurian to the close of the Carboniferous Age, and the final cresting of the series in this Appalachian revolution, that the great features of the continent had been marked out from the earliest time? Even in the Azoic, the same northeast and southwest trend may be observed in Northern New York and beyond Lake Superior, showing that, although the course of the great Azoic lands was partly east and west, the same system of dynamics that characterized succeeding ages was then to some extent apparent.

The first event in the records after the Appalachian revolution, was the gathering up of the sands and rolled fragments of the crystallized rocks and schists along the Atlantic border into beds; not over the whole surface, but in certain valleys, which lie parallel with the Appalachian chain, and which were evidently a result of the foldings of that revolution. The beds are the red sandstones and shales, which stretch on for one hundred and twenty miles in the Connecticut valley; and similar strata occur in Southeastern New York, in New Jersey, Virginia, and North Carolina. These long valleys are believed to have been estuaries, or else river courses.

The period of these deposits is regarded as the earlier Jurassic by Professor W. B. Rogers. Dr. Hitchcock supposes that a portion of the preceding or Triassic Period may be represented.

Many of the layers show, by their shrinkage cracks, ripple-marks, and footprints, as others have observed, that they were formed in shallow waters, or existed as exposed mud-flats. But they accumulated till they were over a thousand feet thick in Virginia, and in New England two or three thousand, according to the lowest estimate. Hence the land must have been sinking to a depth equal to this thickness, as the accumulation went on, since the layers were formed successively at or near the surface.

Is it not plain, then, that the oscillations, so active in the Appalachian revolution, and actually constituting it, had not altogether ceased their movements, although the times were so quiet that numerous birds and reptiles were tenants of the Connecticut region? Is it not clear that these old valleys, occurring at intervals from Nova Scotia to South Carolina, originally made by foldings of the earth's crust, were still sinking?

And did not the tension below of the bending rocks finally cause ruptures? Even so: and the molten rock of the earth's interior which then escaped, through the crystalline rocks beneath and the overlying sandstone, constitutes the

trap mountains, ridges, and dikes, thickly studding the Connecticut Valley, standing in palisades along the Hudson, and diversifying the features of New Jersey and parts of Virginia and North Carolina. The trap is a singularly constant attendant on the sandstone, and everywhere bears evidence of having been thrown out soon after the deposition of the sandstone, or in connection with the formation of its later beds. Even the small sandstone region of Southbury, Ct., has its trap. Like the Appalachian revolution, this epoch had its greatest disturbances at the north.

Thus ended in fire and violence, and probably in submergence beneath the sea, the quiet of the Connecticut valley, where lived, as we now believe, the first birds of creation; kinds that were nameless, until, some countless ages afterwards, President Hitchcock tracked them out, found evidence that they were no unworthy representatives of the feathered tribe, and gave them and their reptile associates befitting appellations.

Such vast regions of eruptions could not have been without effusions of hot water and steam, and copious hot springs. And may not these heated waters and vapors, rising through the crystalline rocks below, have brought up the copper ores, that are now distributed, in some places, through the sandstone? The same cause, too, may have given the prevalent red color to the rock, and produced changes in the adjoining granite.

After the era of these rocks, there is no other American record during the European Jurassic Period.

In the next or Cretaceous Period, the seas once more abound in animal life. The position of the cretaceous beds around the Atlantic border show that the continent then stood above the sea very much as now, except at a lower level. The Mississippi valley, which, from the Silurian, had generally been the region of deeper waters, was even in cretaceous times occupied to a considerable extent by the sea, — the Mexican Gulf then reaching far north, even high up the

Missouri, and covering also a considerable part of Texas and the Rocky Mountain slope.

An age later, the cretaceous species had disappeared, and the Mammalian Age (or the Tertiary, its first Period) begins, with a wholly new Fauna, excepting, according to Professor Tuomey, some half a dozen species, about which however there is much doubt. The continent was now more elevated than in the preceding age, and the salt waters of the Mexican Gulf were withdrawn from the region of Iowa and Wisconsin, so as not to reach beyond the limits of Tennessee.

Two or three times in the course of the Tertiary Period, the life of the seas was exterminated, so that the fossils of the later Tertiary are not identical with any in the earliest beds, — excluding some fish remains, species not confined to the coast waters. The crust of the earth was still oscillating; for the close of the first Tertiary epoch was a time of subsidence; but the oscillation or change of level was slight, and by the end of the Tertiary, the continent on the east stood within a few feet of its present elevation, while the Gulf of Mexico was reduced nearly to its present limits.

I have thus brought this rapid sketch to the close of the Tertiary, having omitted much of great interest, in order to direct attention to the one grand fact, — that the continent from the Potsdam sandstone, or before, to the Upper Tertiary, was one in its progress, — a single consecutive series of events according to a common law. It is seen, that the great system of oscillations, due to force pressing or acting from the southeast, which reached its climax in the rise of the Appalachians, then commenced a decline. We mark these oscillations still producing great results in the Jurassic Period along the whole eastern border from Nova Scotia to the Carolinas. Less effect appears in the Cretaceous Period, and gradually they almost die out as the Tertiary closes, leaving the Mississippi Valley and the eastern shores near their present level.

Thus were the great features of Middle and Eastern North America evolved; nearly all its grand physical events, in-

cluding its devastations and the alternations in its rocks, were consequent upon this system of development.

Moreover, as I have observed, this system was some way connected with the relative positions of the continent and the oceanic basin, — meaning by the latter the profound depressions in which the oceans lie, and not including the shallow-water borders, which are only submerged portions of the Continent.

We need yet more definite knowledge of the Pacific border of North America to complete this subject. It is in accordance with the fact that the highest mountains are there, that volcanoes have been there in action; and also that, in the Tertiary Period, elevations of one to two thousand feet took place; and immediately before the Tertiary a still greater elevation of the Rocky Mountains across from east to west occurred. The system of changes between the Rocky Mountains and the Pacific has been on a grander scale than on the Atlantic border, and also from a different direction, — and this last is an element for whose influence on the general features we cannot yet make full allowance.

Through all this time, central British America appears to have taken little part in the operations; and what changes there were, except, it may be, in the Arctic regions, conformed to the system prevailing farther south, for the rocks of the Jurassic Age, like the Connecticut River sandstone, are found as far north as Prince Edward's Island, in the Gulf of St. Lawrence.

But the Tertiary Period does not close the history of the continent. There is another long Period, the Post-tertiary, — the period of the Drift, of the Mastodon and Elephant, of the lake and river Terraces, of the marine beds on Lake Champlain and the St. Lawrence, — all anterior to the Human Era.

From this time there is a fundamental change in the course of operations. The oscillations are from the north, and no longer from the southeast.

The *drift* is the first great event, as it underlies the other loose material of the surface; and all recognize it as a *northern* phenomenon, connected with northern oscillations.

The upper terrace of the lakes and rivers, and also the marine beds four hundred feet above the level of Lake Champlain, and five hundred above the St. Lawrence, which have been called Laurentian deposits, are marks of a *northern* depression, as no one denies.

The subsequent elevation to the present level again, by stages marked in the lower river terraces, was also *northern*, affecting the region before depressed.

The south felt but slightly these oscillations.

There are thus the following epochs in the Post-tertiary: — the *Drift Epoch;* the *Laurentian Epoch*, an epoch of depression; the *Terrace Epoch*, an epoch of elevation; — *three* in number, unless the Drift and Laurentian Epochs are one and the same.

As this particular point is one of much interest in American Geology, I will briefly review some of the facts connected with the drift.

The drift was one of the most stupendous events in geological history. In some way, by a cause as wide as the continent, — and, I may say, as wide nearly as the world, — stones of all sizes, to immense boulders of one to two thousand tons' weight, were transported, along with gravel and sand, over hills and valleys, deeply scratching the rocks across which they travelled. Although the ocean had full play in the many earlier ages, and an uneasy earth at times must have produced great convulsions, in no rock strata, from the first to the last, do we find imbedded stones or boulders at all comparable in magnitude with the immense blocks that were lifted and borne along for miles in the drift epoch.

Much doubt must remain about the origin of the drift, until the courses of the stones and scratches about mountain ridges and valleys shall have been exactly ascertained. The general course from the North is admitted, but the special facts prov-

ing or disproving a degree of dependence on the configuration of the land have not yet been sufficiently studied.

One theory, the most prevalent, supposes a deep submergence over New England and the North and West, even to a depth of four or five thousand feet, and conceives of icebergs as floating along the blocks of stone, and at bottom scratching the rocks. Another, that of the Professors Rogers, objects to such a submergence, and attributes the result to an incursion of the ocean from the north, in consequence of an earthquake movement beneath the Arctic Seas.

The idea of a submergence is objected to on the ground that the sea has left no proofs of its presence by fossils, or sea-shore terraces or beaches.

Unless the whole continent were submerged, of which there is no evidence whatever, there must have been in the Post-tertiary Period an east-and-west line of sea-shore, say across New Jersey, Pennsylvania, Southern Ohio, and the other States west, or still farther south; and yet no such sea-shore marks now exist to trace its outline, although the ocean must have been a portion of the same that had laid up the Cretaceous and Tertiary beds all along the coasts, and, in fact, already contained the oysters and clams, and many other species of Mollusks which now exist. Can it be, that, contrary to all the ways of the past, such a grand submergence as this view supposes, placing New England four thousand feet under water, could have transpired without a sea-shore record?

Very many have replied in the affirmative; and one able advocate of this view, who sees no difficulty in the total absence of sea-shore terraces or fossils at all levels above the Laurentian beds, finds in the succeeding epoch sea-shore accumulations in all the terraces of our rivers. Why this wonderful contrast? What withheld the waves from acting like waves in the former case, and gave unbounded license in the latter?

This much, then, seems plain, that the evidence, although

negative, is very much like positive proof that the land was not beneath the sea to the extent the explanation of the drift phenomena would require.

There are other objections to this view of submergence. If North America were submerged from the southern boundary-line of the drift far into the Arctic regions, this would have made a much warmer climate for the continent than now; if only half-way, then there is another east-and-west shore line to be traced out, before the fact of the submergence can be admitted. Again, we know how the ice, while a glacier, or along a shore of cliffs, (for all bergs are believed to have once been glaciers,) may receive upon them, or gather up, heavy blocks of stone, even a thousand tons in weight, and bear them off to distant regions, as now happens in the Northern Atlantic. But we have no reason to believe that the massy foot of a berg could pick up such blocks and carry them twenty miles, to drop them again; and hence the short distance of travel would prove that the bergs were made that short distance to the north, and this implies the existence there of glacier valleys and requires a glacier theory.

But without considering other difficulties, I pass to the inquiry, Whether the lands, if not submerged, were at any higher level than now?

There is evidence of striking character, that the regions or coasts over the higher latitudes, in both the northern and southern hemispheres, were once much elevated above their present condition. The *fiords*, or deep coast channels, scores of miles long, that cut up the coast of Norway and Britain, of Maine, Nova Scotia, and Greenland, of Western America from Puget's Sound north, of Southern South America from Chiloe south, of Van Diemen's Land and other southern islands, are all valleys that could not have been scooped out when filled with the ocean's water as now; that could have been formed only when the land in those high latitudes, north and south, was elevated till their profound depths were nearly dry. Whether this elevation was in the period of the Post-

tertiary has not been precisely ascertained. But as they are proof of a north-and-south system of oscillations, the same that was in action in the drift epoch, and as the cold that such a change would occasion is not very distinctly apparent in the Tertiary period, and much less in the earlier, we have reason for referring the greater part of the elevation to that drift era, and for believing that the excavation of these fiord valleys was then in progress. Both fiords and drift are alike high-latitude phenomena on all the continents, north and south. The change of climate between the Cretaceous and Tertiary, and the absence of Tertiary beds north of Cape Cod, may have been connected with an incipient stage in this high-latitude movement.

However this be, there is other evidence, in the cold of the drift period, of some extraordinary cause of cold. The drift in Europe and Britain is generally attributed to glaciers and icebergs during a period of greater cold than now; and the fact of this greater cold is so generally admitted, that it is common to speak of it as the glacial period. Professor Agassiz, moreover, has urged for this continent the glacial theory.

In a memoir of great research, by Mr. Hopkins, of Cambridge, England, the able author maintains that this glacial cold might have been produced over Europe, partly at least, by a diversion of the Gulf Stream from its present position. He seems in his paper to attribute too much effect to the Gulf Stream, and too little to the prevailing currents of the atmosphere; but, setting this aside, it is unfortunate for the hypothesis, that there is no reason to suppose that America was not then as much in the way of such a diversion as now. The small changes of level which the Tertiary and Post-tertiary beds of the Gulf have undergone, prove that the gate of Darien was early closed, and has since continued closed. America, as far as ascertained facts go, has not been submerged to receive the Stream over its surface. If it had been, it would have given other limits to her own drift phenomena; for it is

an important fact that these limits in America and Europe show the very same difference in the climates or in the isothermals as that which now exists.

On the question of the drift, we therefore seem to be forced to conclude, whatever be the difficulties we may encounter from the conclusion, that the continent was not submerged, and therefore icebergs could not have been the main drift agents: the period was a cold or glacial epoch, and the increase of cold was probably produced by an increase in the extent and elevation of northern lands. Further than this, in the explanation of the drift, known facts hardly warrant our going.

If, then, the drift epoch was a period of elevation, it must have been followed by a deep submergence to bring about the depression of the continent, already alluded to, when the ocean stood four hundred feet in Lake Champlain, and a whale (for his bones have been found by the Rev. Z. Thompson of Burlington) was actually stranded on its shores; and when the upper terrace of the rivers was the lower river-flat of the valleys. This submergence, judging from the elevated sea-beaches and terraces, was five hundred feet on the St. Lawrence and Lake Champlain; eighty feet at Augusta, Maine; fifty feet at Lubec; thirty at Sancoti Head, Nantucket; over one hundred at Brooklyn, N. Y.; and two hundred to two hundred and fifty in Central New England, just north of Massachusetts; while south, in South Carolina, it was but eight or ten feet.

But whence the waters to flood valleys so wide, and produce the great alluvial plain constituting the upper terrace, so immensely beyond the capability of the present streams? Perhaps, as has been suggested for the other continent, and by Agassiz for this, from the melting snows of the declining glacier epoch. The frequent absence of fine stratification, so common in the material of this upper terrace, has often been attributed to a glacier origin.

According to this view, the events of the Post-tertiary Pe-

riod in this country make a single consecutive series, dependent mainly on polar or high-latitude oscillations: — an elevation for the *first* or *Glacial Epoch;* a depression for the *second* or *Laurentian Epoch;* a moderate elevation again, to the present height, for the *third* or *Terrace Epoch.*

The same system may, I believe, be detected in Europe; but, like all the geology of that continent, it is complicated by many conflicting results and local exceptions; while North America, as I have said, is like a single unfolding flower in its system of evolutions.

There is the grandeur of nature in the simplicity to which we thus reduce the historical progress of this continent. The prolonged series of oscillations, acting by pressure from the southeast beneath the Atlantic, reach on through immeasurable ages, producing the many changes of level through the Silurian and Devonian, afterwards with greater frequency in the Carboniferous, and then, rising with quickened energy and power, folding the rocks and throwing up the long range of the Appalachians, with vast effusions of heat through the racked and tortured crust, next go on declining as the Jurassic and Cretaceous Periods pass, and finally fade out in the Tertiary. The northern oscillations, perhaps before in progress, then begin to exhibit their effects over the high temperate latitudes, and continue to the Human Era. The sinking of Greenland, now going on, may be another turn in the movement; and it is a significant fact, that, while we have both there and in Sweden northern changes of level in progress, such great secular movements have nowhere been detected on the tropical parts of the continents.

In deducing these conclusions, I have only stated in order the facts as developed by our geologists. Were there time for a more minute survey of details, the results would stand forth in bolder characters.

The sublimity of these continental movements is greatly enhanced when we extend our vision beyond this continent to other parts of the world. It can be no fortunate coincidence

that has produced the parallelism between the Appalachian system and the grand feature lines of Britain, Norway, and Brazil, or that has covered the north and south alike with drift and fiords. But I will not wander, although the field of study is a tempting one.

In thus tracing out the fact, that there has been a plan or system of development in the history of this planet, do we separate the Infinite Creator from his works? Far from it: no more than in tracing the history of a planet. We but study the method in which Boundless Wisdom has chosen to act in creation. For we cannot conceive that to act without plan or order is either a mark of divinity or wisdom. Assuredly it is far from the method of the God of the universe, who has filled all nature with harmonies; and who has exhibited his will and exalted purpose as much in the formation of a continent, to all its details, as in the ordered evolution of a human being. And if man, from studying physical nature, begins to see only a Deity of physical attributes, of mere power and mathematics, he has but to look within at the combination of the affections with intellect, and observe the latter reaching its highest exaltation when the former are supreme, to discover proofs that the highest glory of the Creator consists in the infinitude of his love.

My plan, laid out in view of the limited time of a single address, has led me to pass in silence many points that seem to demand attention or criticism; and also to leave unnoticed the labors of many successful investigators.

There are some subjects, however, which bear on general Geology, that should pass in brief review.

I. The rock-formations in America may in general be shown to be synchronous approximately with beds in the European series. But it is more difficult to prove that catastrophes were synchronous, that is, revolutions limiting the ages or periods.

The revolution closing the Azoic Age, the *first* we distinctly

observe in America, was probably nearly universal over the globe.

An epoch of some disturbance between the Lower and Upper Silurian is recognized on both continents. Yet it was less complete in the destruction of life on Europe than here, more species there surviving the catastrophe, and in this country there was but little displacement of the rocks.

The Silurian and the Devonian Ages each closed in America with no greater revolutions than those minor movements which divided the subordinate periods in those ages; Mr. Hall observes that they blend with one another, and the latter also with the Carboniferous, and that there is no proof of contemporaneous catastrophes giving them like limits here and in Europe.

But after the Carboniferous came the Appalachian revolution, one of the most general periods of catastrophe and metamorphism in the earth's history. Yet in Europe the disturbances were far less general than with us, and occurred along at the beginning and end of the Permian Period.

From this epoch to the close of the Cretaceous, there were no contemporaneous revolutions, as far as we can discover. But the Cretaceous Period terminates in an epoch of catastrophe which was the most universal on record, all foreign Cretaceous species having been exterminated, and all American, with a few doubtful exceptions. This third general revolution was the prelude to the Mammalian Age. But there is no time to do this subject justice, and I pass on, — merely adding, on account of its interest to those who would understand the first chapter of Genesis, that there is no evidence whatever in Geology, that the earth, after its completion, passed through a chaos and a six days' creation at the epoch immediately preceding man, as Buckland, in the younger days of the science, suggested, on *Biblical*, not on geological, ground. No one pretends that there is a fact or hint in Geology to sustain such an idea: moreover, the science is utterly opposed to it.

II. The question of the existence of a distinct *Cambrian system* is decided adversely by the American records. The Mollusca in all their grand divisions appear in the Lower as well as Upper Silurian, and the whole is equally and alike the Molluscan or Silurian Age. The term Cambrian, therefore, if used for fossiliferous strata, must be made subordinate to Silurian.

The *Taconic system* of Emmons has been supposed by its author to have a place inferior to the Cambrian of Sedgwick, or else on a level with it. But the investigations of Hall, Mather, and Rogers, and more lately of Logan and Hunt, have shown that the Taconic slates belong with the upper part of the Lower Silurian, being, in fact, the Hudson River shales, far from the bottom of the scale.

III. The American rocks throw much light on the origin of coal. Professor Henry D. Rogers, in an able paper on the American Coal-fields, has well shown that the condition of a delta or estuary for the growth of the coal-plants, admitted even now by some eminent geologists, is out of the question, unless the whole continent may be so called; for a large part of its surface was covered with the vegetation. Deltas exist where there are large rivers; and such rivers accumulate and flow where there are mountains. How, then, could there have been rivers, or true deltas of much size, in the Coal Period, before the Rocky Mountains or Appalachians were raised? It takes the Andes to make an Amazon. This remark has a wider application than simply to the Coal Era.

IV. In this connection, I add a word on the idea that the rocks of our continent have been supplied with sands and gravel from a continent now sunk in the ocean. No facts prove that such a continent has ever existed, and the whole system of progress, as I have explained, is opposed to it. Moreover, gravel and sands are never drifted away from seashores, except by the very largest of rivers, like the Amazon; and with these, only part of the lightest or finest detritus is carried far away; for much the larger part is returned to the

coast through tidal action, which has a propelling movement shoreward, where there are soundings. The existence of an Amazon on any such Atlantic continent in Silurian, Devonian, or Carboniferous times, is too wild an hypothesis for a moment's indulgence.

V. The bearing of the facts in American Palæontology on the science, might well occupy another full discourse. I will close with brief allusions to some points of general interest.

1. The change in the Fauna of the globe as the Age of Man approaches, is one of the most interesting facts in the earth's history. It was a change not in the types of the races, (for each continent retains its characteristics,) but a remarkable dwindling in the size of species. In North America the Buffalo became the successor to the huge Mastodon, Elephant, and Bootherium; the small Beaver to the great Castoroides; and the existing Carnivora are all comparatively small.

Parallel with this fact, we find that in South America, as Dr. Lund observes, where, in the last age before Man, there were the giant Megatherium and Glyptodon, and other related Edentates, there are now the small Sloths, Armadillos, and Ant-eaters.

So, also, on the Oriental continent, the gigantic Lion, Tiger, Hyena, and Elephant, and other monster quadrupeds, have now their very inferior representatives.

In New Holland, too, the land of Marsupials, there are Marsupials still, but of less magnitude.

2. This American continent has contributed to science a knowledge of some of the earliest traces of Reptiles, — the species of the Pennsylvania coal formation, described by Mr. King and Mr. Lea, and others from the Nova Scotia coal-fields, discovered by Messrs. Dawson and Lyell.

It has afforded the earliest traces of birds thus far deciphered in geological history, — the colossal and smaller waders, whose tracks cover the clayey layers and sandstone of the Jurassic rocks in the Connecticut valley. The earliest

Cetacea yet known are from the American Cretaceous beds, as described by Dr. Leidy. And among the large Mammals which had possession of the renewed world after the Cretaceous life had been swept away, the largest, as far as has been ascertained, lived on this continent. The Palæotheria of the Paris Basin, described by Cuvier, were but half the size of those of Nebraska.

But here our boasting ceases, for, as Agassiz has shown, the present Fauna of America is more analogous to the later Tertiary of Europe than to the existing species of that continent.

In the Palæozoic Ages, to the close of the Coal Period, the American continent was as brilliant and profuse in its life as any other part of the world. It was a period, indeed, when the globe was in an important sense a unit, not individualized in its climates or its distribution of life, and only partially in its seas. But from this time the contrast is most striking.

The whole number of known American species of animals of the Permian, Triassic, Jurassic, Cretaceous, and Tertiary Periods is about two thousand; while in Britain and Europe, a territory even smaller, there were over twenty thousand species. In the Permian we have *none*, while Europe has over two hundred species. In the Triassic, *none;* Europe, one thousand species. In the Jurassic, sixty; Europe, over four thousand. In the Cretaceous, three hundred and fifty to four hundred; Europe, five to six thousand. In the Tertiary, hardly fifteen hundred; Europe, about eight thousand.

America, since Palæozoic times, has therefore been eminent for the poverty of its Fauna.

Again: the Mammalian Age in America, although commencing with huge Pachyderms, shows little progress afterward. The larger quadrupeds continue to be mainly herbivorous, and the Carnivora, the higher group, are few and of comparatively small size. *The Herbivora are still the typical species.* While in Europe and Asia, at the same time, — that is, in the Post-tertiary, — the Carnivora are of great size

and ferocity, far exceeding the largest of modern Lions and Tigers. The single species of Lion described, from a bone from near Natchez, by Dr. Leidy, hardly lessens the contrast.

South America, as has been remarked by Agassiz and others, sustains this inferior position of America. The huge Sloths, Megatheria, and other Edentata of the South, are even lower in grade than the ordinary Herbivora, and place that Southern continent at an inferior level in the scale. Although there were Carnivora, they were much smaller than the European. *The Edentates are*, in fact, *its typical species.*

The supremacy of the great Oriental continent is, therefore, most signally apparent.

The contrast is still greater with Australia and New Zealand, whose past and present Fauna and Flora have been well said by Agassiz and Owen to represent the Jurassic Period, — the present era affording Trigonias, Terebratulæ, Cestraciont Fishes, and the Araucarian Coniferæ, all Jurassic types, besides Kangaroos and Moas. Among Mammals, *the Marsupials*, the lowest of all in the class, *are its typical species.*

Ever since Palæozoic times, therefore, the Oriental Continent, — that is, Europe, Asia, and Africa combined, — has taken the lead in animal life. Through the Reptilian Age, Europe and Asia had species by thousands, while America was almost untenanted. In the later Mammalian Age, North America was yet in the shade, both in its Mammals and lower tribes; South America in still darker shadows; and Australia even deeper still. The earth's antipodes were like light and darkness in their zoölogical contrasts. And was there not in all this a prophetic indication, which had long been growing more and more distinct, that the Eastern Continent would be man's chosen birthplace? that the long series of living beings, which had been in slow progression through incalculable ages, would there at last attain its highest exaltation? that the stupendous system of nature would there be opened to its fullest expansion?

Another of our number has shown in eloquent language how the diversified features and productions of the Old World conspired to adapt it for the childhood and development of the race; and that, when beyond his pupilage, having accomplished his rescue from himself and the tyranny of forces around him, and broken the elements into his service, he needed to emerge from the trammels of the school-house in order to enjoy his fullest freedom of thought and action, and social union. Professor Guyot observes further, that America, ever free, was the appointed land for this freedom and union, — of which its open plains, and oneness of structure, were a fit emblem; and that, although long without signs of progress or hope in its future, this land is to be the centre of hope and light to the world.

In view of all these arrangements, man may well feel exalted. He is the last of the grand series. At his approach, the fierce tribes of the earth drew back, and the race dwindled to one fourth its bulk and ferocity, — the huge Mastodons, Lions, and Hyenas yielding place to other species, better fit to be his attendants, and more in harmony with the new creation.

Partaking of the Divine image, all nature pays him tribute; the universe is his field of study; an eternity his future. Surely it is a high eminence on which he stands.

But yet he is only *one* of the series; one individuality in the vast system. How vain the philosophy which makes the creature the God of nature, or nature its own author! Infinitely beyond man, infinitely beyond all created things, is that Being with whom this system, and the combined systems of immensity, were as one purpose of His will.

# REPORT

## ON THE RECENT PROGRESS

### OF

## ORGANIC CHEMISTRY.

By DR. WOLCOTT GIBBS.

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In attempting to trace the recent progress of Organic Chemistry, there are two points of view from which the subject may with propriety be considered. Either we may confine our attention to the directly positive additions which have been made to our knowledge by the discovery and description of new compounds, or we may consider the true progress of the science to be marked by the development of general laws, and by the birth of leading ideas prolific in new facts. As the term Organic Chemistry is one which is somewhat loosely applied, and which is often made to include the Chemistry of Animal and Vegetable Physiology, it is proper to state that I here employ it in a more limited sense, and that I understand by it that branch of the science which treats of the immediate chemical products of the vital force, as well as of those bodies which are derived, or which may be considered as derived, from these by the processes of the laboratory. It is from the second of the two points of view mentioned above that I propose to consider my subject, and, viewed from this point, particular compounds will be of interest only so far as they serve to illustrate general principles. Four leading theories have, as I think, exerted the most

powerful influence upon the progress of Organic Chemistry during the last ten years. They are the theories of Compound Radicals, of Conjugation, of Homologues, and of Substitutions. For the sake of distinctness, I shall consider these separately, and shall endeavor to refer to each the facts which may fairly be considered as flowing from it, without, of course, implying that in every case the theory has preceded the discovery of the fact. And I shall conclude by presenting a brief sketch of the present condition of the science, and of the questions upon which the opinions of chemists are now divided.

The theory of Compound Radicals, as is well known, was first proposed by Berzelius, in the year 1817, and was supported by him during his subsequent career with the tenacity of conviction and the earnestness which so strikingly marked his scientific character. It was adopted and vigorously supported by Liebig, who, sixteen years later, in conjunction with Wöhler, studied with remarkable success the Benzoyl series, and applied the theory in a new form, by assuming the existence of radicals containing oxygen. Berzelius rejected this view, and, limiting the conception of a compound radical to bodies composed of carbon and hydrogen, introduced the Ethyl theory, and applied it to alcohol and to the ethers which were at that time known. The Ethyl theory, speedily adopted by the German chemists, was carried by Liebig's pupils to England, and even met with a favorable reception from several French chemists of note. In France, however, it soon fell into disfavor. Laurent endeavored to substitute for it his theory of Cores, while others, denouncing compound radicals as purely hypothetical bodies, offered other hypotheses of their own, which had at least the merit of being French. Thus, in a recent treatise, the ethers are derived from carburets of hydrogen homologous with marsh gas, an equivalent of hydrogen being replaced by an equivalent of oxygen plus an equivalent of anhydrous acid. Not a single case is, however, cited in which such a substitution has been actually effected,

and the homologues of marsh gas, at the time the work in question was written, were as purely hypothetical as the compound radicals themselves. In other cases the theory was ingeniously avoided by using the term "residue" in place of radical. Thus in benzamid $NH_2, C_{14}H_5O_2$, it was said that the residue $C_{14}H_5O_2$ replaced an equivalent of hydrogen in the ammonia, the reaction being represented by the equation $NH_3 + C_{14}H_5O_2, Cl = HCl + NH_2, C_{14}H_5O_2$. In like manner the radicals $NO_4$ and $SO_2$ were termed the residues of nitric and sulphuric acid. The investigations of Dr. Hofmann on the ammonias and ammoniums produced an immediate change in the views even of those chemists who had rejected the theory of Compound Radicals as involving unnecessary and uncalled-for hypotheses. These researches established the important fact, that in ammonium, $NH_4$, 1, 2, 3, or 4 equivalents of hydrogen may be replaced by an equal number of equivalents of a zincous or electro-positive radical, like methyl or ethyl; and not merely this, but that four different radicals may be present in an ammonium, and three in an ammonia. Ammonia and ammonium became at once generic, instead of specific, terms. The discovery of Ethylamin and Methylamin by Wurtz had already established the existence of highly volatile ammonias, which could be regarded theoretically as ammonia in which an equivalent of hydrogen is replaced by an equivalent of ethyl or methyl, and this view was actually taken by Wurtz. But the mode of formation of the new alkalies employed by him did not, in itself, suggest the idea of such a replacement, even in the case of a single equivalent of hydrogen. While, therefore, we owe to Wurtz an isolated, though beautiful and fruitful discovery, we must accord to Hofmann the merit, not merely of one of the finest generalizations in the science, but also of one of the most powerful methods of studying internal molecular structure which we possess. Hofmann's memoir was published in the Philosophical Transactions of the Royal Society in 1850. In it he clearly established these facts:—

First. That in either ammonia or ammonium any number of equivalents of hydrogen may be replaced by an equal number of equivalents of a compound radical.

Second. That the order of replacement is indifferent.

Third. That the new ammonias or ammoniums so formed are really such; or, in other words, that the distinctive properties of the primitive substance are not altered by the successive replacements of the hydrogen, excepting only in degree.

The following formulas will serve to illustrate the character of Hofmann's discoveries:—

*Ammonias.*

| | |
|---|---|
| Ammonia . . . | $N.HHH$ |
| Ethylamin . . | $N.HH.C_4H_5$ |
| Diethylamin . . | $N.H.C_4H_5.C_4H_5$ |
| Triethylamin . | $N.C_4H_5.C_4H_5.C_4H_5$ |
| Ethylmethylphenylamin | $N.C_2H_3.C_4H_5.C_{12}H_5$. |

*Ammoniums.*

| | |
|---|---|
| Chloride of Ammonium . . | $N.HHHH,Cl$ |
| " Methyl Ammonium | $N.C_2H_3.HHH,Cl$ |
| " Dimethyl Ammonium | $N.C_2H_3.C_2H_3.HH, Cl$ |
| " Trimethyl Ammonium | $N.C_2H_3.C_2H_3.C_2H_3.H, Cl$ |
| " Tetramethyl Ammonium | $N.C_2H_3.C_2H_3.C_2H_3.C_2H_3, Cl$ |

Ethyl methyl amyl phenyl ammonium Chloride $N.C_4H_5.C_2H_3.C_{10}H_{11}.C_{12}H_5, Cl$

Hofmann's discovery left chemists no alternative. It was of no avail to say that methyl and ethyl, for example, are only conjugates of hydrogen, $C_2H_2, H$ and $C_4H_4, H$, and therefore that the radical theory is not proved by Hofmann's discoveries. For the radical theory makes no assumptions as to the internal molecular structure of the radicals themselves, but only assumes that $C_4H_5$ enters into combination as a whole, and as such replaces hydrogen equivalent for equivalent. When iodide of ethyl, by acting upon ammonia, produces Ethylamin and iodide of hydrogen, there is as real a substitution of ethyl for hydrogen as there is of chlorine for

hydrogen when chlorine acts upon acetic acid. In both cases a binary molecule is presented to a single molecule of hydrogen; one atom of the binary molecule (dyad of Laurent) unites with one of hydrogen, while the other takes the place of the hydrogen in the combination. We must therefore admit, that, whatever be the true constitution of $C_4H_5$, the compound $C_4H_5$ | I acts upon a body containing hydrogen precisely as Cl | Cl does, and $C_4H_5$ is therefore equivalent to Cl, and consequently to H or one equivalent of hydrogen. This is all that the radical theory, as applied at least to ethyl and its compounds, can demand, and a general, though not always cordial, acquiescence in the theory in question has taken the place of the old hostility. It deserves to be mentioned in this place, that ten years before Wurtz's discovery of ethylamin and methylamin, Liebig had foreseen the possible existence of an ammonia in which an equivalent of hydrogen is replaced by one of ethyl, and had asserted that such a body would be analogous to ordinary ammonia, and would possess basic properties. Time has seldom given a more beautiful verification of the predictions of genius.

Hofmann's method of replacing hydrogen in the ammonias and ammoniums has since been frequently employed, not merely in studying the molecular structure of the natural alkaloids by determining how many equivalents of replaceable hydrogen they contain, but also in producing substitutions of hydrogen in other bodies not alkaline in their character. In this manner many new alkaloids have been formed, and a prospect, ever brightening, has been opened of artificially producing in the laboratory some of the most valuable therapeutic agents which we possess.

An important addition to the radical theory has recently been made by Cloez and by Natanson, who have shown that an equivalent of hydrogen in ammonia can be replaced by an equivalent of Formyl, $C_2H$, or of Acetyl, $C_4H_3$, radicals assumed by Berzelius in formic and acetic acids, and whose existence, like that of Ethyl and Methyl, has been stoutly

denied. The new ammonias, which we may call Formylamin and Acetylamin, are less strongly basic than ordinary ammonia, or than the corresponding Ethylamin and Methylamin. This arises from the more highly electro-negative character of Formyl and Acetyl, and the discovery at once clears up all doubts as to the constitution of the extensive class of acids homologous with formic acid, and shows that they are the oxides of electro-negative radicals. It will be remembered, that while the highly electro-positive metals, like sodium and zinc, form with oxygen only protoxides which are basic, the more electro-negative metals, like chromium, iron, and manganese, form acid as well as basic oxides. Now, as Zinin has recently shown that Propionyl, $C_6H_5$,— and therefore by analogy its homologue, Acetyl, — forms a basic protoxide as well as an acid teroxide, we see that Ethyl is to Acetyl what zinc is to iron. Our simple radicals are, then, perfectly represented by their compound analogues. In these cases, also, the radical theory makes no hypothesis with respect to the true molecular structure of the radicals themselves, nor does it assert that all three equivalents of oxygen in any one of these organic acids are present in exactly the same form, since, as in sulphuric acid, one equivalent may be combined in a different manner from the other two, and may be capable of replacement by an equivalent of chlorine or other electro-negative body. The Ethyl and Acetyl theories may then be considered as demonstrated, since they furnish the only means of explaining the fact of the equivalent replacement of hydrogen. But while the researches of Hofmann, and those which have flowed from them, have established the truth of the Berzelian theory of compound radicals as applied to compounds of carbon and hydrogen, they have also shown that the extension of Berzelius's views by Liebig and Wöhler must be received, and that we must admit the existence of radicals containing oxygen. As a supplement to Hofmann's discoveries, Gerhardt has proved that 1, 2, or 3 equivalents of hydrogen in ammonia may be replaced by an equal number of equivalents

of a compound radical containing oxygen, as, for example, $C_{14}H_5O_2$, the Benzoyl of Liebig and Wöhler. Thus we have ammonia $NH_3$, Benzamid $NH_2C_{14}H_5O_2$, Dibenzamid $NH\,(C_{14}H_5O_2)_2$, and Tribenzamid $N\,(C_{14}H\ O_2)_3$. The Benzoyl theory in its original form is thus demonstrated, and it is not only clearly shown that Berzelius was in error in rejecting compound radicals containing oxygen, but that in many substances we must admit the existence of a secondary as well as of a primitive radical. Thus the empirical formula of acetic acid is $C_4H_4O_4$, while its rational formula, if we admit that it contains water, is $C_4H_3O_2 . O + HO$, just as anhydrous sulphuric acid is the oxide of the radical $SO_2$, and anhydrous nitric acid the oxide of $NO_4$. Hence in acetic acid the primitive radical is $C_4H_3$, and the secondary radical $C_4H_3O_2$. Kolbe has proposed to give to the names of those radicals which contain oxygen the termination "oxyl," to distinguish them from primary radicals consisting only of carbon and hydrogen, and for which the termination "yl" has long been in use. This suggestion deserves general adoption. In accordance with it we shall have acetyl $C_4H_3$, and acetoxyl $C_4H_3O_2$, benzoyl $C_{14}H_5$, and benzoxyl $C_{14}H_5O_2$, sulphur S, and sulphuroxyl $SO_2$, nitrogen N, and nitroxyl $NO_4$.

The discovery of Gerhardt stands in the same relation to that of Liebig and Wöhler which that of Hofmann bears to the discovery of Ethylamin by Wurtz. Thus, Benzamid, Dibenzamid, and Tribenzamid, are parallel to Ethylamin, Diethylamin, and Triethylamin. In any triamid the three equivalents of hydrogen of the primitive ammonia may be replaced by three *different* radicals containing oxygen. No replacement of even a single equivalent of hydrogen in ammonium by a radical containing oxygen has yet been observed, but perhaps the natural alkaloids may furnish instances of this. It may further be remarked, that the basic property of ammonia is lost by the substitution even of a single equivalent of hydrogen by a radical containing oxygen; the electronegative character of the latter impressing itself upon the

whole compound, rendering the existence even of acid ammonias not improbable. I shall have occasion to return to this subject.

In connection with the theory of compound radicals, I may properly, as it appears to me, mention the anhydrous organic acids, the discovery of which we also owe to Gerhardt. By the action of chloride of benzoxyl on benzoate of potash, Gerhardt obtained anhydrous benzoic acid, the formation of which may be represented by the equation

$$C_{14}H_5O_2Cl + KO, C_{14}H_5O_3 = 2\ C_{14}H_5O_3 + KCl.$$

Similar reactions have yielded a large number of anhydrous acids, while, by using the chlorides of radicals different from those contained in the potash salts employed, Gerhardt and Chiozza have obtained many new double acids or compounds of two organic acids with each other. These, as a general rule, have very little stability, and are easily separated into their components. Water converts the anhydrous organic acids more or less rapidly into the ordinary hydrates.

Gerhardt's beautiful discovery followed quickly upon a very similar one by Williamson, who, by the action of the iodides of the ethyl series upon potash or soda alcohol, obtained a series of new substances, which may be regarded as alcohols, in which an equivalent of hydrogen is replaced by an equivalent of methyl, ethyl, &c. Thus,

$$C_4H_5O,\ KO + C_4H_5I = 2\ C_4H_5O + KI;$$
$$C_4H_5O,\ KO + C_2H_3I = C_4H_5O,\ C_2H_3O + KI.$$

From these reactions Williamson infers that the equivalent of ether is twice as high as that hitherto adopted, and refers both the ethers and alcohols to the type of water with a double equivalent, $O_2H_2$. On this view alcohol is water in which one equivalent of hydrogen is replaced by one of ethyl, while ether is water in which both equivalents of hydrogen are replaced by ethyl. Thus we have, $O_2\left\{\begin{matrix}H\\H\end{matrix}\right.$ water, $O_2\left\{\begin{matrix}H\\C_4H_5\end{matrix}\right.$ alcohol, $O_2\left\{\begin{matrix}C_4H_5\\C_4H_5\end{matrix}\right.$ ether, $O_2\left\{\begin{matrix}C_2H_3\\C_4H_5\end{matrix}\right.$ methyl-ethyl alcohol.

Gerhardt has extended these views to the organic acids, both hydrous and anhydrous, considering, for example, ordinary acetic acid to be $O_2\left\{\begin{matrix}H\\C_4H_3O_2\end{matrix}\right.$, while anhydrous acetic acid is $O_2\left\{\begin{matrix}C_4H\,O_2\\C_4H_3O_2\end{matrix}\right.$, and aceto-benzoic acid $O_2\left\{\begin{matrix}C_4H_3O_2\\C_{14}H_5O_2\end{matrix}\right.$.

These views, which are much strengthened by the comparison of the physical properties of the alcohols, ethers, and acids, have found many advocates; but as they can scarcely be said as yet to have exercised a positive influence upon the progress of organic chemistry, they do not require further notice in this place. The alcohols discovered by Williamson have not yet been carefully studied. We know only their boiling points and the densities of their vapors, but of their chemical properties and relations we are wholly ignorant. Thus common alcohol yields by oxidation, or better by replacement of hydrogen by oxygen, acetic acid; what is then the corresponding product in the case of methyl-ethyl alcohol, $C_4H_5O + C_2H_3O$? Perhaps either acetate of methyl, or formate of ethyl, $C_4H_3O_3 + C_2H_3O$, or $C_2HO_3 + C_4H_5O$. Before we can arrive at the true theory of the constitution of these and similar bodies, a thorough study of the products of their decomposition, as well as of their general chemical relations, is necessary. In the isolation of the organic radicals some progress has been made, though it is in many cases, to say the least, doubtful whether the substances isolated are the radicals themselves, or only bodies isomeric with them. By the electrolysis of acetate and valerate of potash, Kolbe has obtained bodies having the empirical formulas $C_2H_3$ and $C_8H_9$, and which he regards as methyl and valyl. In like manner, by the action of metallic zinc upon iodide of ethyl, as well as by the decomposition of this latter body by light, Frankland has obtained the body $C_4H_5$, which is either identical or isomeric with ethyl. The chemists of the French school double the equivalents of all these bodies, and regard them as corresponding to two volumes of vapor like free hydrogen, of which, with Berzelius, they consider atom

and volume to be synonymous. Thus, with them, Kolbe's methyl is $\left\{ \begin{matrix} C_2H_3 \\ C_2H_3 \end{matrix} \right.$, corresponding to $\left\{ \begin{matrix} H \\ H \end{matrix} \right.$, the equivalent of hydrogen being one half, if we consider that of oxygen to be eight. The only difference, therefore, between the French and German chemists is this: that while Kolbe asserts that methyl is isolable with the equivalent which it has in iodide of methyl, Gerhardt maintains that the isolated ethyl has an equivalent which is twice as high. On this view, which is strongly supported by the relations between the boiling points and atomic volumes of the bodies in question, free ethyl is to ethyl in combination what free hydrogen is to hydrogen in combination. It will be seen at once, that the question is here the same as in the case of the ethers and organic acids above mentioned. Whichever view be adopted, it cannot, I think, be reasonably doubted that many compound radicals have actually been isolated in the same sense as hydrogen itself. The theory can demand no more than this. If we consider a theory to be only a conception which enables us to classify, arrange, and bring under a single point of view, a great and connected series of well-ascertained facts, then I maintain that the chemical theory of compound radicals is as perfect as any theory in the whole range of the physical sciences.

I pass, in the next place, to the consideration of the theory of Conjugation, if I may be allowed to use the term, understanding by it the union of a body, A, with another body, B, of such a nature that the properties of B are thereby changed in degree, but not in kind. We have here to distinguish three different forms or cases, — conjugate radicals, acids, and bases. Of these three classes of compounds the conjugate radicals, which, in fact, are the primitives of the other two, have been most carefully studied, and deserve the most attention. The starting-point of all investigations of this subject was the celebrated memoir of Bunsen on Kakodyl, a body which has the empirical formula $C_4H_6As$, but which is now recognized as a conjunct of two equivalents of methyl with one of arsenic, and which has the rational formula $2\ C_2H_3, As$.

As a type of the simplest class of metallic conjugate radicals we may take Stannethyl, or ethyl-tin, as I should prefer to call it, the discovery of which is due to Frankland, and which has the formula $C_4H_5,Sn$. It is a colorless, oily liquid, which oxidizes in the air, forming a protoxide, $C_4H_5 . SnO$, which acts as a powerful base, and forms very well defined crystalline salts. The reaction by which this body is formed is represented by the equation $C_4H_5I + 2\ Sn = SnI + C_4H_5 . Sn$; and by a similar reaction aided by heat or light, Frankland has succeeded in preparing other conjugate radicals of analogous constitution. But the type of ethyl-tin is by no means the only or the most interesting one. By the action of iodide of ethyl upon alloys of tin, lead, antimony, arsenic, and bismuth, with potassium or sodium, Löwig has prepared a large number of new radicals, many of which are of very complex constitution, but which may all be considered as composed of *m* equivalents of an element united to *n* equivalents of an organic radical so as to form a conjugate metal.

As antimony, arsenic, and bismuth belong to the same group with nitrogen, it was natural to suppose that the compounds of these metals with three equivalents of ethyl, or of another organic radical, would resemble in chemical properties the ammonias of Hofmann, to which we have already alluded, since $As\ (C_4H_5)_3$ and $Sb\ (C_4H_5)_3$ have the same molecular type as $NH_3$ and $N\ (C_4H_5)_3$. This, however, is not the case; for while ammonia and its derivatives never unite directly with oxygen, chlorine, &c., the radicals $Sb\ (C_4H_5)$ and $As\ (C_4H_5)_3$ form oxides, chlorides, &c., like the metals themselves, and we have such compounds as $Sb\ (C_4H_5)_3\ O_2$, $As\ (C_4H_5)_3\ S_2$, &c. In like manner, when ammonia, $NH_3$, is brought into contact with chlorhydric acid, direct combination ensues, and we have chloride of ammonium formed; when, however, $Sb\ (C_4H_5)_3$ is treated with the same acid, hydrogen is evolved, and we have the chloride of the radical $Sb\ (C_4H_5)_3$, the reaction being represented by the equation $Sb\ (C_4H_5)_3 + 2\ HCl = Sb\ (C_4H_5)_3\ Cl_2 + 2\ H$. From this it is clear that

the bodies $Sb\,(C\,H_5)_3$ and $As\,(C_4H_5)_3$ are not ammonias, but conjugate metals, and their formulas may therefore be written $(C_4H_5)_3\,Sb$ and $(C_4H_5)_3\,As$.

It is easy to show, however, that even in these cases the ammonia type is not completely lost. If we add iodide of ethyl to triethyl-antimony, combination ensues, and we have the iodide of a true ammonium, $Sb\,(C_4H_5)_4\,I$, in which antimony replaces nitrogen, and ethyl replaces hydrogen. The new radical $Sb\,(C_4H_5)_4$ unites with a single equivalent of oxygen to form a powerful base yielding well-crystallized salts, while, like other ammoniums, it does not appear to be isolable, and in this particular differs essentially from the conjugate radicals, most of which can be obtained in the free state. It thus appears that the function of the body $Sb\,(C_4H_5)_3$ is a double one, and that it may play the part of an ammonia as well as of a radical. As a radical, we regard it as antimony coupled with three equivalents of ethyl, which modify the chemical properties and relations of the metal, without, however, so far changing them that they can no longer be recognized.

Frankland has recently directed attention to an extremely remarkable fact in connection with these compounds. Nitrogen, phosphorus, arsenic, antimony, and bismuth are all capable of uniting with five equivalents of oxygen or chlorine as a maximum, while tin unites at most with two, and zinc with one. Now, the radicals $Sb\,(C_4H_5)_3$ and $As\,(C_4H_5)_3$ unite with two equivalents of oxygen or chlorine, the radical $Sb\,(C_4H_5)_4$ with one, the radical $As\,(C_4H_5)_2$ with three, the radical $C\,H_5 . Sn$ with one, while finally the body $C_4H_5 . Zn$ forms no compound with oxygen and chlorine, but is completely decomposed by these bodies, yielding ether and oxide or chloride of zinc. Frankland suggests, that in all these cases the original molecular type of the highest oxide is preserved, so that in the new conjugate radicals ethyl may be regarded as replacing oxygen. Thus we have, —

| | |
|---|---|
| Oxide of zinc | $ZnO$ |
| Zinc ethyl | $Zn\ (C_4H_5)$ |
| Peroxide of tin | $SnOO$ |
| Stannethyl oxide | $Sn\,.\,C_4H_5\,.\,O$ |

Antimonic Acid $$Sb\left\{\begin{matrix}O\\O\\O\\O\\O\end{matrix}\right.$$

Oxide of Stibethylium $$Sb\left\{\begin{matrix}O\\O_4H_5\\O_4H_5\\O_4H_5\\C_4H_5\end{matrix}\right.$$

Oxide of Tristibethyl $$Sb\left\{\begin{matrix}O\\O\\C_4H_5\\C_4H_5\\C_4H_5\end{matrix}\right.$$

Oxide of Kakodyl $$As\left\{\begin{matrix}O\\O\\O\\C_2H_3\\C_2H_3\end{matrix}\right.$$

Should a radical having the formula $Sb\,.\,C_4H_5$ or $As\,.\,C_4H_5$ be hereafter discovered, it ought to unite with four equivalents of oxygen or chlorine. Frankland's view is certainly a most ingenious and suggestive one, and it is impossible to deny that a molecular uniformity of some kind exists in the cases mentioned.

The laborious and patient investigations of Löwig have, however, made us acquainted with a large number of conjugate radicals, the constitution of which is by no means so simple, and which we are at present unable to classify in a perfectly satisfactory manner. Thus we have such compounds as

| | |
|---|---|
| $Sn_2\ (C_4H_5)_2$ | $Sn_2\ (C_4H_5)_3$ |
| $Sn_4\ (C_4H_5)_4$ | $Sn_4\ (C_4H_5)_5$ |
| $Sn_4\ (C_4H_5)_3$ | &c., &c. |

All these radicals combine with one equivalent of oxygen to form basic oxides. Löwig has ingeniously proposed to consider these bodies as corresponding to the ordinary organic radicals composed of carbon and hydrogen, the tin being supposed to replace carbon, and the ethyl to replace hydrogen.

Thus the body $Sn_4\ (C_4H_5)_5$ would be ethyl in which carbon is replaced by tin and hydrogen by ethyl. This view is certainly a bold one, but it has hitherto met with but little favor, though no other theory has been proposed which can take its place. Frankland's view, of course, does not apply to radicals like these.

The conjugate acids have not as yet been very thoroughly studied. In many cases of such acids the radicals themselves have been isolated, as, for example, in kakodylic acid. The researches of Kolbe have, however, made us acquainted with many interesting bodies belonging to this class, and have rendered it probable that the class itself is a very numerous one. Thus the compounds having the formulas $C_2H_3 . S_2O_5 + HO$, $C_4H_5 . S_2O_5 + HO$, &c., may be regarded as dithionic acid, $S_2O_5 + HO$, coupled with methyl and ethyl.

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The Berzelian theory of the constitution of the organic alkaloids, that they are conjugate ammonias, morphine, for instance, $C_{35}H_{19}NO_6 . NH_3$, was never very extensively adopted, and fell to the ground with Hofmann's discovery of the replaceability of hydrogen in ammonia and ammonium by complex radicals. All the alkaloids have since been considered as substituted ammonias or ammoniums, perhaps rather too hastily, since the Berzelian view may still be true in particular cases. Genth's discovery of two bases, in which ammonia acts as the couplet and sesquioxide of cobalt as the body coupled, as well as the subsequent observation, by the writer of this report, of similar bases containing deutoxide of nitrogen, will give, it is hoped, a new impulse to the study of this class of bodies. I may, perhaps, without impropriety, so far anticipate the publication of the results of the joint investigation of Genth and myself, as to state the constitution of some of these bases, more particularly as I have already — at the Cleveland meeting — communicated to the Association a brief account of the more remarkable compounds.

The bases in question may be considered as oxides, chlo-

rides, &c. of conjugate radicals formed by the union of two equivalents of cobalt with a certain number of equivalents of ammonia, or of ammonia and deutoxide of nitrogen. Adopting, with a slight modification, and extending the nomenclature of Frémy, we have the following radicals with the bases resulting from their combination with oxygen: —

| | Radicals. | Bases. |
|---|---|---|
| Roseocobalt | $5\,NH_3 . Co_2$ | $5\,NH_3 . Co_2O_3$ triacid. |
| Luteocobalt | $6\,NH_3 . Co_2$ | $6\,NH_3 . Co_2O_3$ " |
| Purpureocobalt | $5\,NH_3 . Co_2$ | $5\,NH_3 . Co_2O_3$ uniacid. |
| Xanthocobalt | $NO_2 . 5\,NH_3 . Co_2$ | $NO_2 . 5\,NH_3 . Co_2O_3$ " |
| Dixanthocobalt | $2\,NO_2 . 5\,NH_3 . Co_2$ | $2\,NO_2 . 5\,NH_3 . Co_2O_3$ biacid. |

The chlorides of these bases correspond in constitution to the oxides, and form very extensive and well-defined series of double salts with the chlorides of the more electro-negative metals. It is worthy of notice, that while the oxygen bases, whose formulas are written above, may be regarded simply as conjugates of the sesquioxide of cobalt, the sesquioxide itself does not always retain its property of combining with three equivalents of acid. The saturating capacity of the base depends, therefore, in some measure at least, on the nature of the couplet. None of the above assumed radicals have been isolated, nor does it appear probable that they are capable of existing in a free state. The existence of two allotropic forms or modifications of cobalt is rendered probable by the discovery of Purpureocobalt, the constitution of which is identical with that of Roseocobalt, while not merely the crystalline forms of the corresponding compounds, but all the reactions of the two bases, are entirely distinct. Two allotropic forms of the protoxide of cobalt have already been observed by Genth.

Since the discovery of the ammonia-cobalt bases, Claus has obtained ammonia-rhodium and ammonia-iridium bases corresponding to Roseocobalt, and it cannot be doubted that further researches will add greatly to the number of similar compounds. It is certainly very remarkable that the sesqui-

oxide of cobalt, a body which is so unstable that it does not form a single definite combination with acids, by union with ammonia should form a series of powerful bases. No more striking instances of the class of bodies which I have termed *conjugate* could have been furnished.

In the process of conjugation, it will be seen that an inactive body, brought into contact with an active one, becomes itself active and polar, just as a bar of soft iron brought into contact with a magnet becomes itself magnetic, and remains so, so long as the contact is unbroken. I think that there is more in this than a mere superficial analogy.

No theoretical views have done so much to make Organic Chemistry a science, as the discovery of the principle of homologism by Gerhardt. This principle must, for the present, be regarded simply as the expression of an empirical law, that series of bodies, between which there exists a constant difference of constitution, are analogous in chemical properties and relations. The discovery of wood-spirit and the investigation of its properties by Dumas, together with the subsequent discovery of fusel oil by Balard, first suggested the idea that alcohol is to be regarded as a generic, and not merely as a specific term. The same idea was soon applied to other organic compounds, and it gradually became evident that many well-known substances were only types of larger classes of similar bodies. It is, however, to Gerhardt that we owe the first clear perception and definite expression of the precise relation which exists between the chemical constitution of those organic substances which form natural families or groups, like the alcohols, ethers, &c. This relation consists simply in this, that bodies exhibiting a parallelism in chemical properties differ in constitution either by $C_2H_2$, or by some multiple of this expression. Bodies so related are said to be homologous, and the different members of such a series are called homologues. The elegance and simplicity with which whole classes of compounds can thus be brought under one general formula, and treated as a whole, is truly surprising. I

will exemplify this remark by a few instances of homologous series, giving in the case of each the general formula which embraces every member as a particular case.

| Hydrogens. | Acetenes. | Palenes. | Formic Acids. | Oleic Acids. | Oxalic Acids. |
|---|---|---|---|---|---|
| $H$ | $C_2H_2$ | $H_2$ | $C_2H_2O_4$ | $C_6H_4O_4$ | $C_2HO_4$ |
| $C_2H_3$ | $C_4H_4$ | $C_2H_4$ | $C_4H_4O_4$ | $C_8H_6O_4$ | $C_4H_3O_4$ |
| $C_4H_5$ | $C_6H_6$ | $C_4H_6$ | $C_6H_6O_4$ | $C_{10}H_8O_4$ | $C_6H_5O_4$ |
| $C_6H_7$ | $C_8H_8$ | $C_6H_8$ | $C_8H_8O_4$ | $C_{12}H_{10}O_4$ | $C_8H_7O_4$ |
| $C_{2n}H_{2n+1}$ | $C_{2n}H_{2n}$ | $C_{2n}H_{2n+2}$ | $C_{2n}H_{2n}O_4$ | $C_{2n}H_{2n-2}O_4$ | $C_{2n}H_{2n-1}O_4$ |

To each of these general formulas the idea of certain specific properties is attached. Thus it is sufficient to know the general properties and relations of any one member of an homologous series to know those of all the others, which must, of necessity, correspond in kind, though not in degree. Stearic acid, $C_{34}H_{34}O_4$, and acetic acid, $C_4H_4O_4$, belong to the formic acid series. They differ greatly in appearance and in the ordinary physical properties, but chemically there is a a perfect parallelism between them. Of the possible upper limit in the case of each series, we, of course, know nothing; it is probable, however, that in each case such a limit actually exists. It appears, furthermore, desirable to extend the idea of homologism to other cases than where there is merely a difference of constitution of $C_2H_2$, by seeking for general analogies in properties wherever there is any regular and uniform difference of composition whatever. Thus the Phenyl series differs from the Ethyl series by eight equivalents of carbon which the former contains more than the latter, yet there are very strong points of analogy between Phenyl alcohol, $C_{12}H_6O_2$, and common alcohol, $C_4H_6O_2$. We have here a new species of homologism, the homologizing body being $C_8$. Kopp has shown that there exists between the boiling points of the successive homologous bodies of any series a common difference of about 19° C., and this remarkable relation, to which we shall presently return, has been of very great use in determining the true equivalents of many substances, and their position in the series to which they belong.

The theory of substitutions, as is well known, was proposed by Dumas in 1839, and the views of this distinguished chemist were based upon the observation that, in acetic acid, three equivalents of hydrogen could be replaced by three of chlorine, in such a manner that the new substance still possessed strongly acid properties, and, in many particulars, closely resembled ordinary acetic acid. It was hence inferred that chlorine could replace hydrogen, equivalent for equivalent, the properties of the original substance remaining essentially the same in all its derivatives.

It is of course unnecessary in this place to give a history of the controversy which ensued, and in which the most eminent chemists of the day took an active part. While, on the one hand, Berzelius and the electro-chemists maintained that a highly electro-negative body like chlorine could by no means play the part of an electro-positive element like hydrogen, the French chemists, on the other hand, replied by an imposing array of facts which admitted of no simple or satisfactory solution, except upon the theory of a double function of chlorine and similar elements. The question remained, however, undecided, and the views of both parties became more and more modified, until the discovery of the chlorinated alkaloids derived from anilin by Dr. Hofmann at last decided in favor of the modified theory of substitutions. This chemist proved, not merely that one or two equivalents of hydrogen in anilin could be replaced by one or two equivalents of chlorine or bromine, without a loss of basic properties, but also that the bases thus obtained could be reconverted into ordinary anilin. Melsens proved, in like manner, that chloracetic acid could be reconverted into common acetic acid. Thus it was shown that chlorine could replace hydrogen, and hydrogen be substituted for chlorine. In this case, then, it was clearly proved that both parties were right, and both wrong. The French chemists were wrong in asserting that the molecular structure and arrangement of the organic body alone determine its properties, since it has been clearly shown that, by

the replacement even of a single atom of hydrogen by an atom of chlorine, the properties of the primitive undergo a more or less distinct modification. Thus chloranilin is less strongly basic than anilin, and trichloracetic acid a more powerful acid than the acetic.

The results of the investigations of the last few years upon the subject of substitutions may, I think, be summed up in the following propositions: —

1. One or more equivalents of hydrogen in a given organic compound may be replaced by an equal number of equivalents of chlorine, bromine, &c., without an essential change of properties.

2. In all cases, the chemical properties are changed in degree, if not in kind.

3. The more complex the constitution of an organic body, the less marked is the effect produced by the substitution of an equivalent of one element by an equivalent of another.

4. Conversely, the more simple the molecular structure of the primitive, the greater is the change in properties produced by an equivalent substitution.

5. The greater the number of equivalents replaced, the greater will be the change in chemical properties. In many cases, this change becomes so marked, that the properties of the original body are entirely lost, and only its molecular type remains.

6. The greater the difference between the chemical properties of the replaced and replacing substances, the greater will be the change in chemical character produced by the substitution. Hence electro-positive or zincous bodies replace each other, as we have seen in the case of Hofmann's ammonias, without modifying in any essential particular the properties of the primitive substance. And the same must be true for electro-negative or chlorous bodies, though their mutual replacements have hitherto been little studied.

From all these facts, it is clear that the chemical nature of a compound depends upon the *nature* of its constituents, and not upon their *arrangement* alone, as has been maintained.

If we adopt Ampère's theory of the binary structure of the elements, it appears to me that we can easily account for the replacement of an electro-positive body like hydrogen by an electro-negative one like chlorine. For of two associated molecules of chlorine, one will be positive and the other negative. Suppose that we are to replace one equivalent of hydrogen in anilin, $C_{12}H_7N$, by an equivalent of chlorine. We may assume that, in the presence of chlorine, the molecule of anilin becomes polar, an equivalent of hydrogen being positive, while the other elements, taken together, form the negative molecule. Then the reaction which ensues may be represented by the equation

$$C_{12}\overset{-}{H_6}N.\overset{+}{H} + \overset{-}{Cl}\overset{+}{Cl} = C_{12}\overset{-}{H_6}N.\overset{+}{Cl} + \overset{+}{H}\overset{-}{Cl}.$$

In this case it is clear that it is an electro-positive molecule of chlorine which replaces the more electro-positive hydrogen, and it is not difficult to conceive that the chlorine so introduced into the organic body may retain its electro-positive character. Of course, even the most highly electro-positive chlorine which we can produce must be electro-negative with respect to hydrogen, and this will explain the change in chemical character which its introduction produces. I offer these views with diffidence; they form part of a general theory of chemical polarity upon which I am engaged.

It is still a matter of dispute with chemists whether chlorine can replace oxygen, equivalent for equivalent. I consider the numerous class of bodies termed oxy-chlorides as furnishing conclusive evidence upon this point, and will cite, among organic compounds, the bodies whose formulas are as follows: —

| | | | |
|---|---|---|---|
| Primitives | $C_4H_3O_3 + C_4H_3O_3$. | $C_4H_3O_3 + C_2HO_3$. | $C_4H_3O_3$. |
| Derivatives | $C_4H_3O_3 + C_4H_3OCl_2$. | $C_4H_3O_3 + C_2HOCl_2$. | $C_4H_3O.S.Cl$. |

It is not doubted, I believe, by any chemist, that sulphur and oxygen freely replace each other in combination. The fact, as I shall show, is an important one.

To conclude this report according to the plan which I

have laid down, it remains to offer a sketch of the present condition of Organic Chemistry. We have seen that the state of our knowledge compels the adoption both of the theory of compound radicals and of that of substitutions. There is, I think, but little difference of opinion between chemists upon these two points. The law of homology is universally admitted, while upon the theory of conjugate bodies there is at present but little discussion, our knowledge of the subject being still very imperfect. The great question of the day, as it seems to me, is a question of equivalents. What are the true equivalents of oxygen and its congeners, of chlorine and the chloroid bodies, of hydrogen and the metals, and, finally, of carbon and its compounds? Are we to adapt our combining weights to the combining volumes, so that the equivalents of all bodies shall be represented by the same volume, or shall we retain the equivalents now received, and admit that the combining volumes in the gaseous state are different? Lastly, are we to be content with the empirical formulas of compound substances, or may we hope to penetrate into their molecular structure so as finally to obtain their true rational constitution? These questions have all originated in the remarkable observations of Laurent and Gerhardt upon the number of equivalents which enter into the constitution of organic compounds. These chemists, by a careful examination of all known and well-determined formulas, have, I believe, indisputably proved that — with the single exception of carbonic oxide — in every organic compound not possessing acid properties, and not containing one of a certain class of acids to which I shall presently allude, the number of equivalents of carbon ($C = 6$) is even. For this there is certainly a reason. Gerhardt and Laurent assume that the equivalent of carbon is 12, and not 6, as heretofore maintained, and that consequently in all our formulas the number of equivalents of this element must be reduced one half; and at first sight this appears to be a perfectly reasonable assumption. On the other hand, however, in a very

large number of organic acids, — carbonic acid being one, — the number of equivalents of carbon is odd, if the acids in question be considered as unibasic. Gerhardt and Laurent double the equivalents of these acids, and regard them as bibasic; in this manner the new equivalent of carbon, viz. twelve, satisfies all the formulas. As a proof of the correctness of this view, the French chemists show that all of these organic acids possess distinct but common properties, which in any view oblige us to place them in a class by themselves. Why not, then, assume the totality of these common properties as the definition of a bibasic acid? But admit this definition, and many inorganic acids, as, for example, sulphurous and sulphuric acids, become bibasic, and here we soon meet with serious difficulties. But, furthermore, Gerhardt and Laurent show that, in very many organic compounds, the number of equivalents of oxygen is also even. They therefore double the equivalent of this element, and are consequently obliged to double the equivalents of all those bodies, inorganic as well as organic, in which the number of equivalents of oxygen, as they are now written, is odd. In this manner the formula of water becomes $O'H_2$, ether is $C'_4H_{10}O'$, and anhydrous acetic acid $C'_4H_6O'_3$, where the accent is used to distinguish the new equivalent. It will be immediately seen that, if the equivalent of oxygen be doubled, a radical change must be made in all the formulas of inorganic chemistry into which oxygen enters. Thus, all protoxides must be written $R_2O'$; the deutoxides become $RO'$; the nitrates become $NO'_3R$, and the nitrites $NO'_2R$. The supposition of the French chemists, that the volumes of all bodies in the gaseous state are equal, leads also at once to the conclusion, that the equivalents of oxygen and carbon are respectively sixteen and twelve ($H = 1$). Finally, a careful study of the relations between the physical properties of organic compounds *appears* to afford a complete confirmation of the new views. Thus, Kopp long since showed that between the boiling points of the successive members of any homologous series there exists

a common difference of about 19° C. In a recent discussion of the formulas of the alcohols, ethers, and anhydrous organic acids, Will has shown that, if Kopp's law be admitted, the formulas of the ethers and anhydrous acids must be doubled, as the double equivalent of oxygen requires. Again, Kopp has proved that, in order to obtain the true specific volumes of organic compounds, the densities of the bodies must be taken at or near their boiling points. By *specific volumes* it will be remembered that we understand the relative spaces occupied by the equivalents, and these are calculated by dividing the equivalents by the corresponding densities. Now, a comparison of the specific volumes of fluid compounds appears to show that the equivalents of ether and the anhydrous acids above mentioned are twice as high as usually admitted. The boiling points, as well as the specific volumes, of the fluid compounds hitherto examined, may be brought under one point of view by assuming, with Williamson and Gerhardt, that the formula of water is $O'H_2$, and that the unibasic acids, ethers, alcohols, and anhydrous acids may all be considered as derived from water by the replacement of one or both the equivalents of hydrogen by other radicals. The following formulas will sufficiently illustrate these points:—

| Water. | Alcohol. | Ether. | Acetic Acid. |
|---|---|---|---|
| $O'\left\{\begin{array}{l}H\\H\end{array}\right.$ | $O'\left\{\begin{array}{l}H\\C_4H_5\end{array}\right.$ | $O'\left\{\begin{array}{l}C_4H_5\\C_4H_5\end{array}\right.$ | $O'\left\{\begin{array}{l}C_4H_3O'\\H\end{array}\right.$ |

| Anh. Ac. Acid. | Mixed Ether. | Mix. Acid. |
|---|---|---|
| $O'\left\{\begin{array}{l}C_4H_3O'\\C_4H_2O'\end{array}\right.$ | $O'\left\{\begin{array}{l}C_2H_3\\C_4H_5\end{array}\right.$ | $O'\left\{\begin{array}{l}C_4H_3O'\\C_2HO'\end{array}\right.$. |

Purely physical considerations certainly, then, give us every reason to hope that we may hereafter determine the true molecular structure of organic bodies, and that our knowledge is not to be limited to empirical formulas.

It must then, I think, be admitted that the evidence in favor of doubling the received equivalents of carbon and oxygen is of great weight, and that the adoption of this change will greatly simplify most of our formulas. Let us then briefly

consider the objections to these changes. In the first place, I remark, that if the equivalent of oxygen be doubled, that of sulphur must also be changed in the same ratio. Now, the volume of the vapor of sulphur is one third of that of oxygen. If we admit, with the French chemists, that all bodies have the same volume in the gaseous state, the equivalent of sulphur as now received must be multiplied, not by 2, but by 6. There will then be no analogy between the formulas of the compounds of sulphur and those of oxygen, between which the chemical parallelism is perfect. Again, the researches of Frankland have recently shown that the volume of gaseous zinc is not two, like that of hydrogen, which the French chemists consider as the type of all the metals, but one, like that of oxygen and carbon. And, generally, experiment shows that elements which belong to the same natural group do not always possess the same volume in the state of vapor. It becomes, then, from this point of view, very difficult to admit the theory of equal volumes and the equivalents which flow from it. In the second place, it appears, I think, necessary to admit that chlorine with the equivalent 35.5 = (2 vols.) can replace oxygen with the equivalent 8 = (1 vol.), and it is certain that sulphur eq. 16 = ($\frac{1}{3}$ vol.) can replace oxygen, the combining volume of which is three times as high. The third obvious difficulty arises from the constitution of the salts of the sesquioxides. Thus alum is $KO, SO_3 + Al_2O_3, 3\,SO_3 + 24\,HO$, with the usually received equivalents. But if sulphuric acid be bibasic, how are we to explain such compounds as $Al_2O_3, 3\,SO_3$? Gerhardt very ingeniously supposes that in the so-called *sesquioxides* there exist metals with two thirds of the equivalents of the same metals in their *protoxides*. Thus sesquioxide of iron is not $Fe_2O_3$, but 3 feO, where fe = $\frac{2}{3}$ Fe. This view leads at once to many very simple and beautiful formulas, but it leaves unexplained the fact that the new protoxide feO and its congeners so frequently enter into combination in the proportion of three equivalents. Lastly, we may remark that the indications afforded

by a comparison of physical constants are at best somewhat precarious and uncertain. Thus may it not be that, in the case of Kopp's law of the difference between the boiling points of homologous bodies, the true expression should be, "Homologous bodies differ in boiling points either by 19° C., or by some multiple of this number"? Again, while the boiling points of the oxygen compounds of ethyl, acetyl, &c. appear to confirm the views of Laurent and Gerhardt, those of the corresponding sulphur compounds appear to follow entirely different laws. Thus the sulphides of ethyl and methyl are less volatile than sulphide of hydrogen, while the oxides of the same radicals are more volatile than water. The oxygen alcohols of ethyl and methyl are less volatile than their ethers, the sulphur alcohols are more volatile than the corresponding sulphides. If the existence of a certain law, connecting the boiling points of a series of oxides, proves that these oxides have a particular molecular constitution, then the absence of such a law, or the existence of a converse one, proves that the corresponding sulphides have a different constitution. It is to be hoped that the very interesting and valuable researches of Kopp on the boiling points and specific volumes of organic bodies will be extended to those which contain sulphur. These then are the questions upon which the opinions of chemists are now divided. They amount to presenting us with this alternative,— Shall we extend the laws which govern the constitution of inorganic bodies to organic compounds, or shall organic chemistry embrace inorganic chemistry as a particular case?

In concluding a report which, I am conscious, presents but a superficial sketch of its subject, I have only to ask that the nature of the occasion, and the point of view from which I have been compelled to write, may be duly considered.

# PROCEEDINGS

OF THE

# PROVIDENCE MEETING, 1855.

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## COMMUNICATIONS.

## A. MATHEMATICS AND PHYSICS.

### I. MATHEMATICS.

#### 1. On Solutions by Construction. By Rev. Thomas Hill, of Waltham, Mass.

The refined analysis of modern days, aided by the invention of logarithms and other facilities for computation, has almost entirely banished solutions by construction from the office of the engineer. It has also done a more serious mischief, by almost entirely banishing Geometry from the course of education.

I need not attempt to show that this must be a mischievous error, for every student of the mathematical sciences knows that Geometry must ever be the foundation of all learning. I shall confine myself to the other point, — the value to the practical mathematician of solutions by construction. My attention has been called anew to this subject by a memoir of Professor Cooke in the Memoirs of the American Academy, in which he illustrates a paper upon the compounds of zinc and antimony by a curve line, possessing singular properties, which could not have been brought to light if the curve had not been first made visible to the eye. When a function is geometrically constructed, or a series of numbers rendered visible by being

represented by lines, the continuity or discontinuity of the curve is much more readily perceived than it can be from an inspection of the numbers themselves.

It is true that geometrical construction can seldom be accurate in the fourth decimal place, counting from the highest place mapped, and therefore, when greater accuracy than this is required, calculation is indispensable. But in very many of the practical cases which actually occur, no greater accuracy is desired, or is even possible; and in such cases we should avail ourselves of geometrical construction, if that construction will give us the result more rapidly.

*Interpolation*

Affords us a good example. In interpolating among a series of observed numbers, some assumption as to the nature of the curve must always be made, and hence perfect accuracy of results is impossible. We may therefore generally obtain equally good results by construction, and in much less time than would be required to calculate them.

If there are three observed points, a circle passing through them is the most natural curve. If there are more than three, we may connect them by a succession of chords, and the mutual intersection of perpendiculars raised upon the centres of these chords will make a part of a polygon tangent to a curve, whose involute will be a curve passing through the given points. By drawing this evolute by the eye, and setting in a few pins, we can, with a string, strike the required curve.

In this way we can almost instantly make any required number of interpolations, accurate to the hundredth of an inch, which, on the usual scale of units in mapping, is as accurate as the observations require; that is, it is within hundredths of the difference between two successive observations. If greater accuracy is required, recourse must be had to calculation, by Alexander's formula in Silliman's Journal for January, 1849, or some other usual formula.

That formula and my own mode by projecting the evolute both give curves which exactly satisfy all the observations. But there are frequently cases in which we know that the observations ought not to be exactly satisfied. We may, for instance, know that the curve ought to be a parabola or ellipse, and yet find that the curve through

the given points has contrary flexures. In this case the alternate observations may be connected, and two evolutes found. An evolute may then be drawn by the eye equidistant between them, and the involute drawn with a string long enough to make it pass equidistantly among the observed points. In case of sufficient observations to allow the two curves to be well determined, this plan is very successful. In the case of a small number of points, there is nothing left but for the eye to determine what weight shall be allowed to each observation, an operation which, in ordinary cases, may be as safely trusted to the eye as to the pencil. The "fudging" of practical engineers, and the rule of Double Position, stand on the same foundation. They should not be frowned upon as inexact modes of discovering truth. Their method lies at the basis not only of all science, but of politics, agriculture, commerce, medicine, jurisprudence, and I almost might say morality.

### *Rejection of Doubtful Observations.*

When observations are mapped for the purpose of interpolation, or for other purposes, the eye will instantly detect the observations to be rejected. In most practical cases, excepting in the marvellously minute and accurate calculations of astronomy, the application of Peirce's Criterion would consume time disproportionate in value to the result. In all such cases, a glance of the eye at the observations, when mapped or plotted, will tell which observation ought to be rejected, and the mapping of the observations for such a purpose need not be at all carefully done. Where the eye hesitates, the formula would also hesitate; that is, it would require the numbers to be carried out to a higher decimal place.

### *Solutions of Problems.*

In the solutions of problems by geometrical construction, we are to be guided always by two considerations, — the degree of accuracy desired, and the relative rapidity of construction and computation. For ordinary calculations of trigonometry, nothing would be gained in time by geometry, and much lost in accuracy. But there are other problems of more intricacy, and in which great accuracy is not required, in which a mechanical construction gives results very rapidly. In eclipses of the sun, for example, it seems a great waste of labor to

calculate with accuracy the phases for the whole continent, when the day of the eclipse may be signalized by one of those extended north-east storms that cloud half the continent with an impenetrable veil. To save this waste of labor, I was requested some years ago by Professor Peirce to invent a machine to perform these calculations. By this machine I computed more than two hundred phases of the eclipse of May, 1854, in ten hours' time, and found that most of my places agreed to the nearest minute with the accurate map afterwards issued for the Nautical Almanac Office. Last Friday I spent about four hours in calculating the chart, accompanying this paper, of the eclipse of March, 1857.*

But I have said enough to illustrate the central thought of this paper. I wished to show that there are many cases in which the scientific computer could save time, without the sacrifice of any desirable degree of accuracy, by appealing to his eye and compasses to do the work of the pen; and many others in which, like Professor Cooke, in the memoir to which I have alluded, he could obtain much clearer ideas of the nature of a function by looking at the observations of its phenomena drawn as a curve, instead of being arranged in tabular numbers. The time of a good computer is certainly too valuable to be wasted in labors upon rough data, to which construction is better adapted; or in revising intricate and tedious calculations, when geometrical tests can be applied which will decide the question at a glance.

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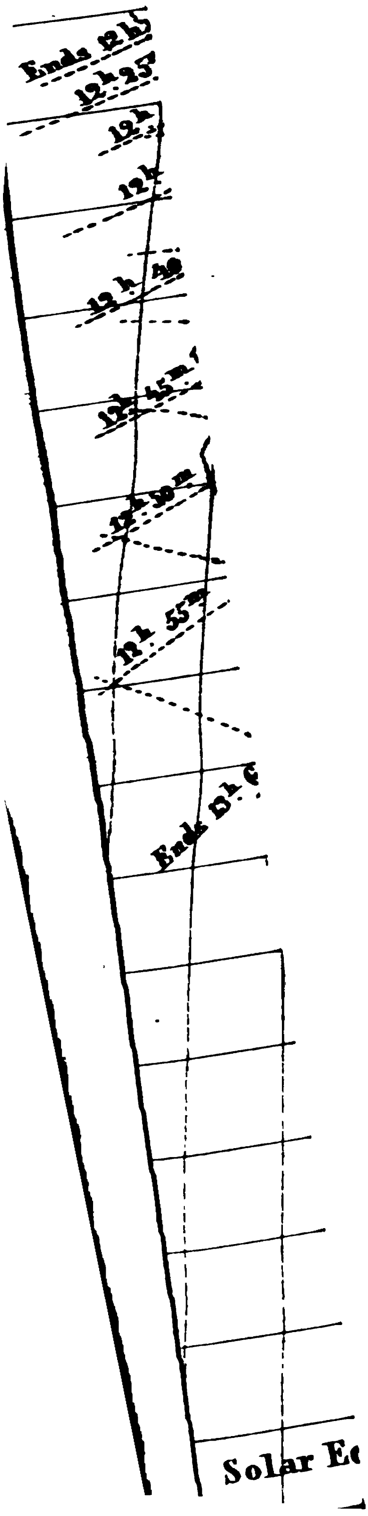
* The chart has had some additional labor since bestowed upon it, but not more than six hours were necessary from the time the Tables of the Moon were first opened, until the chart was finished in its present form.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2. Abstract of a Paper on Researches in Analytic Morphology. Transformation of Curves. By Professor Benjamin Peirce, of Cambridge.

The singular changes which the forms of curves undergo by variations of the elements upon which they depend, deserve philosophical study, and may serve to illustrate the varieties of form which are observed in the organic world to originate from the different fundamental types. The following are the special points which are the subject of the present investigation.

1st. *The recurrence of the same forms in radically different types.* Thus the circle is one of the conic sections, it is an elastic curve, it is the extreme limit of the curves which are similar to their own involute, it belongs to the class of catenary upon any vertical surface of revolution, and on account of its simplicity must occur in almost every symmetrical system of curves. Its occurrence in each of these classes is not, therefore, a valid argument against a system of classification in which any or all of these types should be recognized as separate groups, nor is it a proof that such a system is artificial and opposed to sound logic. But, on the contrary, it would seem to indicate that, as in the forms which might originate in our intellect there would be a true crossing and interlacing of thought, the same thing may be reasonably expected in the forms which proceed from the Divine intellect, so that in a true system of nature the very same type would be found in quite different portions of the classification. In the same way the equilateral hyperbola which is associated with the ellipse as a conic section, is wholly separated from this curve, and even from all the other hyperbolas when it becomes a catenary upon the vertical cone. Geometry is rich in similar instances of this recurrence of the same form in different types.

2d. *The great variety of apparently different forms which are subject to the same intellectual law of development.* The conic sections are familiar examples of this phenomenon, and the elastic curve, which begins in the straight line, is slightly undulatory in its first curvation, then bends back upon itself in large folds which please the eye by their regular intersections, then is compressed into the simple form of a figure *eight* (8), by still further pressure assumes another variety of

intersecting folds, becomes then a system of delicate loops which twist alternately in opposite directions, and are continually removed from each other until they are reduced to a single loop with two infinite branches which affect at their extremities a form of especial simplicity. The elastic curve next assumes a form of loops in which the curvation is always in the same direction, and these loops approach by increased compression until they intersect each other, and are finally reduced to the single form of the circle which may be called the elastic ring.

3d. *The different appearance of the same intellectual idea when clothed in a different material form.* Thus the variety of form of the elastic curve disappears in the motion of the pendulum, which is the expression of the same law of thought, but which only exhibits the monotony of perpetual vibration, or the equal monotony of continual rotation in the same direction with periodic returns of the same velocity of motion, when it is urged with sufficient rapidity to make a complete revolution. The conceptions of the ellipse and hyperbola with reference to the distance of their points from their foci seem to be fitly expressed in the difference of their forms; but when these same conceptions are transferred to the surface of the sphere, the forms become identical, and the conceptions are to be regarded as slightly different and mutually dependent properties of the same curve.

4th. *The changes in the mutual relation of the parts of the curve which accompany its changes of form.* This is particularly conspicuous when the curve passes through any of its singular states. Thus when the axes of the hyperbola vanish, the curve becomes two straight lines which cut each other, but one half of each line belongs to one of the branches of the original hyperbola, while the other half belongs to the other branch. These same two lines are also the evanescent state of a different hyperbola, of which the branches are situated in the other angles of the lines. If the lines are assumed to represent the first hyperbola, the halves which represent a branch by their combination are different from those which belong together in the second hyperbola; so that, upon reaching the point of intersection by moving towards it along one of the lines, it is uncertain always on which half of the other line the motion should be properly continued. It is interesting to observe that, on the occurrence of such cases in

nature, the decision is always avoided by some simultaneous phenomenon which renders it unnecessary. Thus, in the rotation of a free solid, when the body begins to rotate about an axis of rotation which is upon the line of direct approach to the mean axis of rotation, it would be doubtful, when the axis of rotation reached the mean axis, in which direction it should begin to move away from this position; but this uncertainty is wholly speculative, for the velocity of approach towards the mean axis constantly diminishes until it is infinitely small in the immediate vicinity of this axis, so that the decision of the question must be postponed till the close of an infinite time.

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### 3. Abstract of a Paper upon the Solution of the Adams Prize Problem for 1857. By Professor Benjamin Peirce, of Cambridge.

The following announcement of the Adams Prize is from the "Quarterly Journal of Pure and Applied Mathematics," edited by Professor Sylvester and Mr. Ferrers, assisted by Professor Stokes, Mr. Cayley, and M. Hermite: —

"The University of Cambridge having accepted a fund raised by several members of St. John's College, for the purpose of founding a Prize, to be called the Adams Prize, for the best essay on some subject of pure mathematics, astronomy, or other branch of natural philosophy, the prize to be given once in two years, and to be open to the competition of all persons who have at any time been admitted to a degree in this University, the examiners have given notice that the following is the subject for the prize to be adjudged in 1857: —

"*The Motion of Saturn's Rings.*

"The problem may be treated on the supposition that the system of rings is exactly or very approximately concentric with Saturn, and symmetrically disposed about the plane of his equator, and different hypotheses may be made respecting the physical constitution of the rings. It may be supposed, (1.) that they are rigid; (2.) that they are fluid, or in part aeriform; (3.) that they consist of masses of matter not mutually coherent. The question will be considered to be answered by ascertaining, on these hypotheses severally, whether the

conditions of mechanical stability are satisfied by the mutual attractions and motions of the planet and the rings.

"It is desirable that an attempt should also be made to determine on which of the above hypotheses the appearances both of the bright rings and the recently discovered dark ring may be most satisfactorily explained; and to indicate any cause to which a change of form, such as is supposed, from a comparison of modern with the earliest observations, to have taken place, may be attributed.

"The essay must be sent in to the Vice-Chancellor on or before the 16th of October, 1856, privately; each is to have some motto prefixed, and to be accompanied by a paper sealed up, with the same motto outside, which paper is to inclose another, folded up, having the candidate's name and college written within.

"The papers containing the names of those candidates who may not succeed, will be destroyed unopened.

"Any candidate is at liberty to send in his essay printed or lithographed.

"The successful candidate will receive £130. He is required to print his essay at his own expense, and to present a copy to the University Library, to the Library of St. John's College, and to each of the four Examiners."

Prizes of this kind have not yet been established in America, and it is to be hoped that they never will be; for they serve to divert an excess of intellectual power from its natural channel, and concentrate it upon a single object of research, obtaining thereby many solutions of a problem, of which only one can be required. They are peculiarly unsuited to an atmosphere of free thought, and can only receive the cordial approbation and response of minds which are hardened to the trammels of despotism or oligarchy. The only prizes which can be regarded as of unalloyed utility are those which, like the Rumford Premium, the medals of the Royal Society, the Cuvier Prize, and many others connected with the science of France and Germany, are awarded to successful labors actually performed under the unrestricted influence of genuine philosophic inspiration. The present case deserves especial criticism, in that a prize is not likely to elevate the science of a community from which foreign competition is carefully excluded.

The present subject of the Prize has been already discussed before

this Association ; and in a memoir, which was read at the Cincinnati meeting, the fundamental problem was solved in a most general form, and the principles of the solution have been published in Gould's Astronomical Journal, with sufficient detail to enable any geometer of high ability to supply the deficient formulæ. Other pursuits have prevented the final working of the formulæ into forms of sufficient elegance for publication. The restrictions of the present prize greatly facilitate the discussion, and enable the mathematical development to assume such a simplicity that it may easily come within the grasp of ordinary geometrical capacity, and I have therefore thought it expedient to present it, in this form, to the Association, and it will be immediately published in Gould's Journal. The only important change from the general mode of discussion consists in the application of the theory of the Potential, given by Gauss, and still further developed in a treatise of Analytic Mechanics which is soon to be published. The argument against the solidity of the ring will probably be admitted to be satisfactory and complete. The objections to a ring composed of discontinuous materials are derived from the internal currents to which such a system must be liable, and which cannot fail to reduce it either to a powder or to a fluid state ; so that no other reasonable hypothesis remains but that of a fluid ring.

The various changes in the constitution of the ring, which have been observed by astronomers, are confirmatory evidence of its fluid nature. The appearance and disappearance of the finer divisions indicate internal commotions and collisions, which are likely to be associated with a loss of living force. The decrease of the internal diameter of the ring, which is indicated by the able researches of Otto Struve, with an accumulation of testimony which is hard to be resisted, may perhaps be the effect, and therefore a manifestation, of this loss of power; in which case, it would seem that a portion of the ring is likely to fall upon the primary before another century has elapsed. Or this phenomenon may be a great secular tide produced by the action of the satellites, which, however, could hardly occur without a sensible loss of force; so that even in this case an important change in the constitution of the ring would not seem to be a very remote contingency. But the action of the satellites upon the ring is not included in the demands of the prize, so that the discussion of the tides of the ring will be postponed to a subsequent occasion.

### 4. Abstract of a Paper on Partial Multipliers of Differential Equations. By Professor Benjamin Peirce, of Cambridge.

Two systems of multipliers of simultaneous differential equations have been made the subject of previous investigation, one of which was discovered by Euler, and the other by Jacobi. The contrast between these multipliers is curious and interesting; for every system of Eulerian multipliers corresponds to a first integral of the given equations, while the Jacobian multiplier corresponds to a last integral of the equations. In comparing and examining these multipliers, I have been led to the discovery of a general system of multipliers, which includes both of those previously known. They are such that, for every system of these multipliers which is of any order whatever, there is a corresponding integral of the given equations. The mathematical definition and investigation of these multipliers will be published in Gould's Astronomical Journal and in the System of Analytic Mechanics.

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### 5. Abstract of a Paper upon the Catenary on the Vertical Right Cone. By Professor Benjamin Peirce, of Cambridge.

The investigation of the form of a uniform chain upon a surface of revolution, of which the axis is vertical, may be referred to that of the *asymptotic equilateral hyperboloid*, which has the same axis; that is, to the surface formed by the revolution of an equilateral hyperbola about either of its asymptotes. The catenary upon this hyperboloid crosses the meridian curve at a constant angle; and if the centre of the hyperboloid is rightly placed upon the axis of the given surface, the angles which the curve makes with the meridian of the surface will be the same as all the circles of its intersection with the hyperboloid. If, then, the hyperboloid is made of such a magnitude as to pass through one of the limiting points of the catenary, that is, one of the points in which the curve is horizontal, it must pass through all the other limiting points of the catenary. Hence the limits of the

catenary are derived from the simple inspection of the points of intersection of the meridian curve of the surface of revolution, with a fitly adjusted equilateral hyperbola. In the case of the right cone, the meridian curve is a straight line, so that the determination of the points of the catenary upon a vertical right cone involves the discussion of the intersections of a straight line with an equilateral hyperbola.

The catenary extends, in all cases, over those portions of the surface of revolution which are more remote from the axis of revolution than those of the limiting hyperboloid which are upon the same level, and is excluded from the other portions of this surface. In the case of the vertical right cone, the catenary may consist of three portions, of which the intermediate portion may return into itself, while the other two portions extend to infinity; or the intermediate portion may wholly disappear. The complete definition of this catenary is effected by the aid of elliptic integrals.

The formulæ will be published in the Analytic Mechanics.

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6. Abstract of a Paper upon the Motion of a Heavy Body on the Circumference of a Circle which rotates uniformly about a Vertical Axis. By Professor Benjamin Peirce, of *Cambridge.*

The motion, in this problem, may be either oscillatory or continually in the same direction, with a certain law of periodicity. In the case of the motion continued in the same direction, there are usually two points of maximum and two of minimum velocity, which are determined by the intersections of the circumference with an equilateral hyperbola which is drawn in its plane so as to pass through the centre of the circle, with one of its asymptotes horizontal, and of which the co-ordinates of the centre are quite simply determined. When the motion is oscillatory, the two points of maximum velocity may remain, but one of the points of minimum velocity must be on the portion of the circumference which the body does not pass through.

The case of the coincidence of one of the points of maximum with one of those of minimum velocity, leads to a new and simple geometrical property of the equilateral hyperbola.

The case in which the initial velocity of the body is just sufficient

to carry it to one of the points of minimum velocity, admits of complete integration.

The full investigation of this problem is contained in the Analytic Mechanics.

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### 7. Abstract of a Paper on the Resistance to the Motion of the Pendulum. By Professor Benjamin Peirce, of Cambridge.

This paper was devoted to the examination and discussion of the experiments of Newton, Dubuat, Borda, Bessel, and Baily upon the vibrations of pendulums, and much doubt was thrown upon the correctness of the generally received opinion, that the resistance to the motion of a very delicately mounted pendulum is exclusively attributable to the atmosphere. It was suggested that a sensible part of the motion which was thought to be lost from this cause, might be carried off by molecular vibration through the point of support, and this subject seems to deserve careful examination by well-conducted experiments.

The details of this communication will be published in the Analytic Mechanics.

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## II. ASTRONOMY.

### 1. On the Temperature of the Planets, and on some of the Conclusions resulting from this Temperature. By Professor Elias Loomis, of New York.

I propose to inquire into the probable temperature of the different bodies which compose our solar system, and shall briefly advert to a few of the conclusions resulting from this temperature. I am aware of the uncertain nature of many of the data involved in this inquiry, and that there is room for some diversity of opinion respecting my conclusions; but if this communication shall have the effect to stimulate others to an investigation of the same subject, my labor will not be without its reward.

I shall commence my examination with that body with which we are best acquainted, and shall inquire what would be the temperature of our globe if the heat of the sun were withdrawn; or what would be the temperature indicated by a thermometer placed where the earth now is, supposing the bodies which compose the solar system to be annihilated. It is evident that the planetary spaces have a certain constant temperature, which is independent of the presence of the sun, and of the original heat which the earth and planets have preserved; for, otherwise, the polar regions of the earth would be subject to an intense cold, and the decrease of temperature from the equator to the poles would be far more rapid than what we actually observe. This constant temperature of space is necessarily lower than the mean temperature of the coldest regions of the earth; but perhaps not lower than those occasional extremes which may result from evaporation and an extraordinary expansion of air. The mean temperature of the month of January at Jakutzh, Siberia, in Lat. 62°, according to Professor Dove, is 45° below zero of Fahrenheit; and the thermometer at that place has been observed to sink to 76° below zero. We must conclude that the former temperature was somewhat influenced by the action of the sun, for the polar regions during the winter do not entirely lose the effect received from the sun's rays during the preceding summer; and through the intervention of winds, there is a continued interchange between the temperature of the polar and the equatorial regions.

The temperature of the planetary spaces has been variously estimated by different philosophers. Poisson estimated it at 8° above zero of Fahrenheit; but how it is possible that the temperature which our globe would take if the sun did not heat it at all, should be higher than the mean temperature of many points of its surface exposed to the solar rays for more than six months of the year, is a paradox which Poisson himself could not explain. Valz estimated the temperature of the planetary spaces at 49° below zero; Fourier at 58°; Arago, 70°; Ivory, 74°; Peclet, 76°; Laplace, 91°; Saigey, 96°; Sir J. Herschel, 132°; and Pouillet estimated it as at least 175° below zero. The mean of all these estimates is 81° below zero, which I adopt as a tolerable approximation to the temperature of the planetary spaces. In forming this mean, I allow to each of the estimates an equal weight, because I think it probable that the estimate of Pouillet errs as much on one extreme as that of Poisson does on the other.

The temperature of the earth's equator is about 82°. But were it not for the influence of the sun, this temperature would be 81° below zero; for the internal heat of the earth, however great it may be at considerable depths, is insensible at the surface. The effect of the sun's rays is therefore to elevate the mean temperature of the equator 163°, and the mean temperature of the poles about 70°.

If now we assume that the intensity of the sun's heat varies inversely as the square of the distance, we can compute the mean temperature which the earth would have if situated at the distance of either of the other planets from the sun. We shall find that, at the distance of Uranus or Neptune, the temperature of its equator would differ less than one degree from that of the celestial spaces; at the distance of Saturn, it would differ less than two degrees; and at the distance of Jupiter, the temperature of its equator would be only six degrees above that of the celestial spaces. Each of these planets is much larger than the earth, and for that reason would be longer in losing its primitive heat; but as soon as a solid crust of a few miles in depth was formed, it is probable that the temperature of the surface would be but slightly influenced by the internal heat. In other words, we conclude that the temperature of the surface of Jupiter, and of all the more remote planets, is sensibly the same as that of the celestial spaces, or 81° below zero of Fahrenheit.

This conclusion will not be materially affected by supposing these planets to have a much greater power of absorbing the sun's heat than the earth; for the same physical conditions which increase the absorbing power increase also the radiating power; so that although a planet might absorb more heat during the day, it would lose more heat during the night by radiation.

An atmosphere tends, by its mobility, to equalize the effect of the sun's action; and it also tends to increase the mean temperature of the planet. The heat which comes directly from the sun penetrates the air more readily than the heat which proceeds from non-luminous sources. Were it not for the mobility of the air, the heat of the sun would therefore accumulate in the lower strata of the atmosphere, which would thus acquire a very high temperature; but since the air rises as soon as it is heated, the radiation of its heat is thereby promoted; and the effects which would take place in a transparent and solid atmosphere are greatly diminished, though not entirely neutralized in their character. Making the most liberal allowance for the

effect of an atmosphere, however dense, we cannot suppose the mean temperature of Jupiter's equator to be less than 70° below zero, and that of the remoter planets less than about 80° below zero.

If the earth were situated at the distance of Mars, the heat which its equatorial regions would receive from the sun would amount to 70°, corresponding to a mean temperature of 11° below zero at the equator, and of 51° below zero at the poles. There is nothing in the atmosphere of Mars to lead us to infer that these numbers differ much from the actual temperature of that planet.

If the earth were situated at the distance of Venus, the heat which its equatorial regions would receive from the sun would amount to 311°, corresponding to a temperature of 230° at the equator, and of 52° at the poles. As Venus is admitted to have a dense atmosphere, it is probable that its actual temperature is not below the preceding estimate. The mean temperature of Mercury's equator, computed in the same manner, is 1006°, and that of its poles 386°.

If the moon had an atmosphere of the same density as the earth, its mean temperature would be the same as that of the earth, since it has the same mean distance from the sun; but since it has no appreciable atmosphere, its mean temperature must be lowered. I think we shall not be far from the truth in assuming the mean temperature of the moon's equator at 40°; but this temperature must be subject to far greater variations than that of the earth, because there is no atmosphere with its clouds to protect the moon's surface from the full effect of the sun's rays during their long day, which is twenty-eight times the length of our day; and radiation is entirely unimpeded during their night, which is also twenty-eight times the length of our night.

Let us now inquire how far the temperatures assigned for the different planets are compatible with the existence of animal or vegetable life. We have found that the temperature of every part of the surface of Jupiter, as well as that of the more remote planets, is not far from 80° below zero. We may then conclude that no form of animal or vegetable life with which we are acquainted can exist upon either of these planets.

We have found upon Mars a mean temperature of 11° below zero at the equator, and of 51° below zero at the poles. On the summits of mountains, and in the polar regions of the earth, the snow sometimes assumes a red tinge, produced by particles of coloring matter

less than the thousandth of an inch in diameter. These particles have been discovered to be of a vegetable character. A species of vegetation may therefore exist even at the temperature of a polar winter. But this vegetation is wholly microscopic, and, so far as we are acquainted, the temperature of Mars is incompatible with any form of animal or vegetable life exceeding the humblest dimensions.

The mean temperature of the equator of Venus is above that of boiling water, while at its poles we find a mean temperature of 52°. The polar regions of Venus have, therefore, a temperature adapted to the development of animal and vegetable life in their highest perfection, while at the equator no form of life with which we are acquainted could exist.

The temperature of the surface of Mercury, even at its poles, is too elevated for the support of any form of animal or vegetable life.

The existence of life upon the moon is impossible on account of the absence of an atmosphere. I am aware that Professor Hansen has expressed the opinion, that the centre of gravity of the moon does not coincide with its centre of figure, but is about thirty-six miles more distant from us; and hence, that between that hemisphere of the moon which is turned towards the earth, and that which is turned away from us, there must exist a considerable difference with respect to level, climate, &c. If we suppose the figure of the moon to be a sphere, (and observation has never indicated any inequality in its diameters,) then, according to Professor Hansen, the centre of the visible disc of the moon lies about thirty-six miles above the mean level of the moon, and the centre of the opposite hemisphere lies about as much below the same level. If the moon had an atmosphere of the same density as the earth, this atmosphere would be wholly withdrawn from the middle of the hemisphere which is turned towards the earth, as it would be from the summit of a mountain thirty-six miles in height; but on the opposite hemisphere the atmosphere would have a proportionally greater density. Professor Hansen admits that near the moon's limb we might reasonably expect to discover some trace of an atmosphere. But since no appreciable refraction has been observed in the case of any occultation of a star by the moon, we conclude that there is no sensible atmosphere at the moon's limb, and consequently there can be no dense atmosphere on the opposite hemisphere of the moon.

We have concluded the temperature of Saturn to be about 80° below zero. Some have inferred that Saturn's ring was a liquid body; but what substance could retain the liquid condition at so low a temperature? Not only water, and the more common liquids on the earth's surface, solidify at a much higher temperature, but so also do most of the acids, as nitric acid, sulphuric acid, &c. Indeed, pure alcohol is almost the only substance with which we are generally familiar, which can endure so low a temperature without solidifying. The specific gravity of alcohol does not differ much from the specific gravity of Saturn, as determined by astronomical observations.

It may be said that we know nothing of the composition of the liquids which may exist on the surface of Saturn, and that the Creator may have furnished that planet with a liquid covering suited to its condition, but entirely unlike anything with which we are acquainted. If, however, the solar system is *one system*, and was evolved from the elementary condition under the operation of general laws, as geologists are pretty well agreed in maintaining, then each of the planets is probably composed mainly of the same elementary substances; and since these elements can only combine in certain definite proportions, every substance existing on Saturn also exists, *potentially*, if not *actually*, in the laboratory of the terrestrial chemist. This conclusion is confirmed by an examination of Meteorites, which are believed to be bodies foreign to the earth, and which contain no elements not found in terrestrial bodies. If the progress of scientific discovery should confirm the conclusion that alcohol is the prevalent liquid on the surface of Saturn, then it may be proper to inquire, Whether the stomachs of animals may be so constituted that alcohol shall be an innocent beverage?

There is a different substance known to chemists, which some may conceive to constitute the prevalent liquid on Saturn. Common water is a compound formed by the union of one atom of oxygen with one atom of hydrogen. There is another compound formed by the union of two atoms of oxygen with one atom of hydrogen, and this is called the deutoxide of hydrogen. This substance remains fluid at every degree of cold which has been applied to it. It is, however, heavier than water, a circumstance which appears to decide that this substance is not the prevalent liquid on Saturn.

I will venture to suggest, whether all the peculiarities of Saturn's

ring, including the apparently variable number and breadth of the divisions, as well as the recent formation of a new ring, may not be explained by supposing the ring to consist of an immense number of solid bodies, of small dimensions, not cohering together, each revolving independently about the primary, and forming in effect an immense number of independent moons. We know from the example of the nebulæ, that distinct points of light, when sufficiently near to each other, may produce the impression of a uniformly illumined surface. The mutual perturbations of these moons might easily change the number and breadth of the divisions of the rings, and the contracting of the orbits of some of the moons might form a new ring of variable dimensions; while its faint light and wonderful transparency would be explained by supposing the moons to be separated from each other by intervals greater than in the case of the old rings.

About the polar regions of Mars are observed circular spots of dazzling whiteness, which have suggested the idea of polar snows accumulated during the long winter, and which are partially dissolved during the protracted summer. We have concluded that the mean temperature of the equator of Mars is 11° below zero, and that of its poles 50° below zero. With such a temperature, terrestrial snow would never dissolve, and we must call upon the chemists to inform us what can be the composition of Martial snow which melts at a temperature of 30° or 40° below zero. Solid carbonic acid presents very much the appearance of terrestrial snow, but hitherto it has not been solidified without enormous pressure combined with intense cold. It would doubtless be gratifying to the chemists, and perhaps also to the geologists, to find solid carbonic acid heaped up in piles of snowy whiteness on a neighboring planet; but we shall hesitate to admit such a conclusion, when we find that the force of gravity on Mars is only one half what it is on the earth.

Cyanogen, a compound of two atoms of carbon with one atom of nitrogen, becomes solid at a temperature of thirty degrees below zero of Fahrenheit.

These remarks may suffice to show that the chemists may be called upon to decide respecting questions having important applications to Astronomy.

2. New Tables for determining the Values of those Coefficients in the Perturbative Function of Planetary Motion depending upon the Ratios of the Mean Distances. By J. D. Runkle, Assistant at American Nautical Almanac Office. (By Permission of Superintendent of the Nautical Almanac.)

The first important step in the reduction of the planetary perturbations to numbers, is the determination of those coefficients depending upon the ratios of the mean distances.

This work has been done by different astronomers, but last and most completely by Leverrier, whose results were published in 1841. They do not include Neptune; and besides, Professor Peirce has made changes in some of the mean distances, making a redetermination for the whole system desirable. At Professor Peirce's suggestion, and with the approval of Commander Davis, the Superintendent of the American Ephemeris and Nautical Almanac, with whose sanction these remarks are submitted, I have undertaken this work as part of the systematic labor of a thorough revision of most of the planetary theories, now being carried on in the office of the Nautical Almanac, as fast as can be done consistently with the demands which the regular issues of that work make upon the annual appropriations made by Congress for its support.

If I had merely obtained the desired results, however great the labor, it could hardly have claimed the attention of the Association. But during some preliminary inquiries, I was led to a generalization, which I hope astronomers may receive with indulgence, if not with favor. Each one of these coefficients depends upon a series, arranged according to ascending powers of the ratios of the mean distances, taken less than unity, and usually denoted by $a$. Leverrier transformed the series given in the theories of Laplace and Legendre into others converging more rapidly, and the coefficients of the different powers of $a$ in these new series have received the name of the *Leverrier coefficients.*

At the request of the Superintendent of the American Nautical Almanac, the values of these coefficients were computed by the late S. C. Walker, assisted by Mr. Pourtalès, and are published in an Appendix to that work for 1857. This carefully prepared paper has been

of great aid to me, and especially the manuscript sheets containing the numerical values of the coefficients, which were better adapted to the changes which the form of my tables demanded. If, as usual, we denote the coefficients depending upon $a$ by $b_s^i$, $D_a b_s^i$, $D_a^2 b_s^i$, &c., we see, since the addition of Neptune and twenty-nine asteroids to the catalogue of known planets, that there are twenty-eight different values of $a$, for each of which the values of these coefficients must be determined.

The first question which suggested itself was, How do these coefficients vary with $a$?

Now, it is plain that if this variation is slow, terminating in low orders of differences, we may not only make this circumstance a check upon the accuracy of the work, as far as the different values of any one function is concerned, but we may also tabulate the function with reference to $a$ as an argument, and afterwards enter these tables with the special values of $a$ for the system, and take out the corresponding values of the coefficients.

It was soon found, however, that these variations, instead of being slow, were in most cases so rapid as to make them entirely useless, with any ordinary amount of labor, for the purposes indicated.

If, however, we denote any one of these coefficients by $f(a)$, and write

$$f(a) = \text{a series},$$

may we not find ·

$$f(a) = f'(a) \text{ (a transformed series)},$$

in which $f'(a)$ is an exact function of $a$, involving nearly the whole variation of $f(a)$, while the transformed series shall vary so slowly with reference to $a$, as to be perfectly adapted to the ends already specified? This is the idea which I have found eminently adapted; and, fortunately, only slight and quite obvious changes in Leverrier's series were needed, thus making the valuable labor of Mr. Walker entirely available with corresponding modifications.

With the special value of $a$, for those planets whose mutual perturbations we wish to estimate, enter the tables and take out the corresponding values of the series, which multiply by $f'(a)$, and we have the value of $f(a)$, the required coefficient.

We conclude, then, that the whole question of computation, transformation of series, rate of approximation, &c., is finally settled. For

any subsequent investigations which shall change the values of the mean distances, it will only be necessary to enter the tables with the corrected values of $a$, and take out anew the corresponding coefficients.

This form of tables is equally adapted to any planets which may hereafter be discovered. Leverrier, with great additional labor, gave these coefficients for three out of four of the old asteroids. My tables give the values for these asteroids with a few hours' labor, and not only for these, but for all which are, or are to be, discovered.

I am authorized by the Superintendent of the Nautical Almanac to say, that these tables will be printed and distributed among astronomers as soon as practicable.

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3. New Tables for converting Longitudes and Latitudes into Right Ascensions and Declinations. By J. D. Runkle, Assistant at American Nautical Almanac Office. (By Permission of Superintendent of the Nautical Almanac.)

A single case of this problem, although not one of the most attractive in Astronomy, presents no great labor; but when it must be repeated hundreds and thousands of times, as is the case especially in the preparation of the Lunar Ephemeris, it becomes excessively tedious, so much so as strongly to suggest the desirableness of finding some means of curtailing the labor of some of its unattractive proportions. For this reason, I have made this problem the subject of more or less study as often as I have been obliged to come in contact with it.

I am not aware of any previous tables for this purpose, except those published by Professor Encke, in the *Jahrbuch*, which, from their form and want of approximation, are entirely unfitted either for rapid work or delicate results.

At last I have hit upon a single table, which, from its form, takes into account all the possible variations of all the elements involved in the problem, with the greatest simplicity and accuracy; and I feel confident that it will reduce its solution to the smallest amount of

labor of which it is susceptible. I am authorized by Commander Davis to communicate an explanation of this table to the Association.

If, at equidistant intervals (say 20′) on both sides of the ecliptic, we draw circles of latitude, and compute the right ascensions and declinations of equidistant points on these circles, including the ecliptic, or, in other words, their equatorial co-ordinates, and under the corresponding constant latitudes arrange these co-ordinates to the longitude as an argument, it is evident that we may make the variations of these co-ordinates relatively to the *argument* as small as we please, by taking its intervals sufficiently small. Again, it is equally evident that, with a constant longitude, we may make the variations of these co-ordinates relatively to the latitude as small as we please by taking sufficiently small latitude intervals.

Now, it is found that latitude intervals of 20′ take the differences of the variations of these co-ordinates, or, in other words, their second differences, entirely out of the account; while intervals of 15′ in the longitude argument do the same thing so nearly, that in the same part of the table, where, for extreme accuracy, they may not be neglected, they are so small as to be accounted for with trifling labor.

The following are the order and names of the headings of the different columns of the table for a constant latitude: —

1. Longitude argument.
2. Right ascension.
3. Log. variation of A. R. for 1′ of longitude.
4. Log. variation of A. R. for 1′ of latitude.
5. Log. coefficient of the difference between the obliquity for which the table is constructed, and that of the given date, which we will call $\Delta\omega$.

There are corresponding columns for the declination. All these log. variations are given for the same points as the co-ordinates.

Now, it is evident that, if we enter these tables with a given longitude and latitude, to find the corresponding A. R. and Decl. we must reduce the log. variations for 1′ of longitude to the circle of the given latitude, and the log. variations for 1′ of latitude to the given longitude. But these changes are simple proportional parts of the differences of the log. variations, and only need, on the margin of each page, proportional parts of the differences which it contains.

It is obvious that these proportional parts are equally useful in taking account of second differences whenever it is necessary.

After taking out the log. variations corresponding to the given longitude and latitude, it will only be necessary to multiply them by the excess of these data above their nearest argument values to find the corrections for the tabular A. R. and Decl.

The correction for change in the obliquity needs no further explanation.

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4. Contributions to the Atmospherology of the Sun. By Dr. C. H. F. Peters, of Cambridge.

Our knowledge of the physical constitution of the surface of the sun has made very little or no progress since the time of the elder Herschel. This would prove, either that Herschel's observations are so complete that nothing more remains to be investigated, or that the *central* body of our system has been neglected, while nebulæ and double stars, moon and planets, have been the object of very elaborate researches. Each alternative seems to be the case. By employing similar means, and with the same method, that is to say by simple *contemplation*, it will scarcely be possible to discover anything not already reported by that eminent observer. Only a more favorable sky, as I shall show by example hereafter, may disclose some new and important phenomena. Unfortunately, all the more powerful telescopes are mounted in climates not well adapted for solar observations. But there remains another way of investigating the processes producing those singular changes in the sun's atmosphere, which exhibit themselves as spots, faculæ, and otherwise, a way which has been set aside too much in this subject; I mean by *numerical calculation*. Certainly it is not enough to tell the number of spots for every day, nor to determine occasionally from a larger one the elements of rotation; it seems necessary to follow the spots or faculæ in their relation to the sun's body and to each other, by computing their heliographic positions from exact measurements, made, if possible, from day to day. This way is, indeed, a little troublesome, but nevertheless promises very interesting results.

I have the honor to lay before the Association some drawn from a series of observations which I began at Na year 1845, especially with the view to ascertain whether o surface certain fixed localities do exist, where the spots nating.

I may state beforehand, that all the measurements are t the equatorial of the Observatory at Capodimonte, the tele which, of four feet focal length and three inches and a half a is a most excellent one, from the hands of Reichenbach. For ing the physical phenomena the ten-foot Fraunhofer was recu provided with a contrivance suggested by Melloni, cutting off th of heat, but not disturbing those of light. Of every spot pres something definite, the difference from the sun's centre was mined in right ascension by repeated transits, and in declinati the three-foot circle, at intervals, when possible, of one or two Moreover, the principal systems of spots were sketched, a prec necessary in order to avoid mistakes in identifying the spots obs on subsequent days. From the so determined differences in and Decl. the heliocentric situation relative to the sun's equato been computed, by assuming for the beginning of the year 1846 longitude of the equator's ascending node upon the ecliptic to be 13′, its inclination 7° 9′, Mr. Laugier's values, which I have fo pretty near the truth. Thus are obtained the heliographic latitude an angle, which I shall call the *argument of latitude;* it is the lo tude reckoned from that point of the equator which, at that mom is in the ecliptic or in the node. But in comparing together differ spots observed at different times, it is convenient to establish a fi meridian, and (since there is no fixed point always visible upon t sun) I have considered that meridian as the first, which at the begi ning of 1846 (Naples mean noon) passed through the ascendi node. Then, in order to find the meridian actually passing, a know edge of the daily motion, or of the time of rotation, is required. Th value employed (14° 2′.04 for the daily motion, or 25$^{d}$.652 for th time of rotation) has been deduced as a mean from the observation of all the spots. For the following investigation, the first three months have been excluded as being less accurately observed, and moreover, disjoined by an interruption of several months. Likewise the observations following October, 1846, were too isolated to be made use of.

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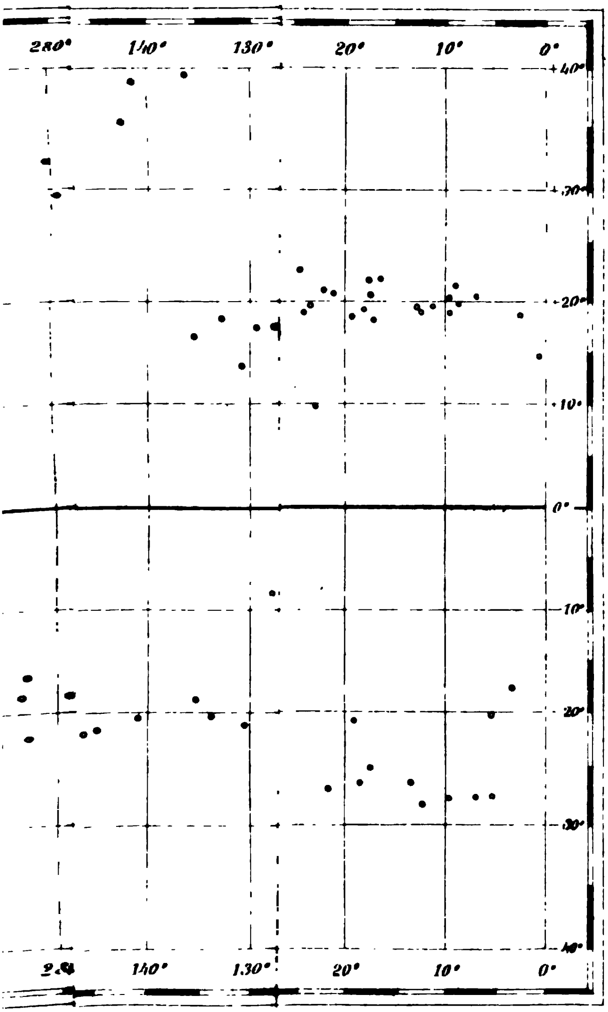


Thus an uninterrupted series of thirteen months remained, from September, 1845, to October, 1846, subministering 813 places of 286 spots. These have been projected in the accompanying map, as far as their mean places.

The first fact, now, which offers itself, in comparing the heliographic places of one and the same spot for different days, is, that the spots are not invariably attached to the sun's surface, but have *proper motions.* Before stating this, due regard should be had to the probable errors that the determination of the compared places may be liable to. This probable error, in my observations, of a difference between a spot and the sun's centre, resulted to be in A. R. 3″ in arc, in Decl. nearly 5″, consequently in all 6″. This would produce in the heliocentric place an error of 215 times 6″ multiplied by the secant of the angle at the sun's centre between earth and spot, 215 being the ratio of the mean distance of the earth to the sun's semidiameter. Near the centre of the sun's disc, then, the probable error would be about 20′; for the angle at the sun's centre equal to 45° it would be 30′, and it would increase rapidly as the spot approaches the limb. I sought to avoid this increase by repeating the observations the more, the nearer the spot was to the limb. And therefore, on the whole, the probable (or more justly speaking the *mean*) error of the heliocentric place as arising from this source may be taken equal to 20′. But a second source we find in the variability of the shape of the spot itself from one day to the other. There is a continual change going on in the spots; less perhaps in the isolated ones, more in those which are in the neighborhood of others, and seem to form part of a system. However, those cases where the change of form was too manifest may be omitted; and we may assume, then, on the average, that two places of a spot as determined on different days ought to agree within half a degree. But now we meet differences of several degrees. Does this not indicate clearly a movement of the spot, especially if, as often, in a *series* of determined places these differences appear to be affected with the same sign?

Wherever in nature a motion is observed, inducement is given to research of laws and of forces causing it. Though, at the first glance, a decrease in latitude seemed predominant, still sometimes this appeared so mixed up with a movement in different sense, that it is only after having carefully examined and combined the circumstances

under which every spot was situated, and after having paid special attention to the arising of the individual spots, that I dare to pronounce the two following theses: —

1. *All the spots have a tendency to move towards the equator.*

2. *Whenever a spot is breaking out in the neighborhood of another, the latter is removing itself towards the opposite side.*

The first or general kind of motion, concealed, if the interval of time

### TABLE A.

*Heliographic Latitudes of Spots which performed an entire Revolution.*

(Mean of the determinations in each appearance.)

| Spot. No. | No. of Obs. | Mean Epoch of Observation. | Heliographic Latitude. | Spot. No. | No. of Obs. | Mean Epoch of Observation. | Heliographic Latitude. |
|---|---|---|---|---|---|---|---|
| | | d. | ° ′ | | | d. | ° ′ |
| 6 | 5 | —106.818 | —27 21 | 80 | 2 | + 93.479 | +31 46 |
| 286 | 4 | 83.568 | 25 54 | 81 | 6 | 118.718 | 28 31 |
| | | | | 77 | 4 | 142.733 | 24 32 |
| 94 | 6 | — 99.442 | +19 54 | | | | |
| 86 | 6 | 76.984 | 17 12 | 279 | 3 | +111.394 | +18 52 |
| | | | | 272 | 5 | 136.972 | 18 37 |
| 180 | 3 | — 65.313 | —17 30 | | | | |
| 177 | 2 | 41.566 | 17 9 | 244 | 3 | +109.764 | —24 6 |
| | | | | 232 | 5 | 134.401 | 22 11 |
| 151 | 1 | — 34.066 | +14 30 | 210 | 3 | 159.661 | 21 41 |
| 147 | 5 | 14.780 | 14 24 | | | | |
| | | | | 261 | 3 | +109.764 | +21 12 |
| 15 | 7 | — 24.777 | +18 32 | 260 | 2 | 133.463 | 20 42 |
| 10 | 7 | + 2.423 | 18 29 | | | | |
| 8 | 4 | 24.960 | 18 4 | 208 | 3 | +134.649 | +17 41 |
| | | | | 202 | 3 | 159.661 | 17 42 |
| 35 | 5 | + 7.820 | +21 48 | | | | |
| 31 | 2 | 27.552 | 19 16 | 79 | 1 | +176.028 | —17 41 |
| | | | | 53 | 5 | 198.841 | 16 4 |
| 26 | 3 | + 8.007 | +18 0 | 48 | 4 | 224.531 | 14 27 |
| 19 | 4 | 27.742 | 17 38 | | | | |
| | | | | 226 | 5 | +244.259 | +28 34 |
| 229 | 6 | + 23.018 | —18 11 | 212 | 1 | 266.024 | 26 44 |
| 228 | 2 | 50.071 | 17 35 | | | | |
| 233 | 4 | 78.775 | 16 50 | 135 | 2 | +211.034 | —21 50 |
| | | | | 118 | 5 | 233.428 | 21 7 |
| 22 | 5 | + 29.186 | +21 11 | 120 | 3 | 256.356 | 21 7 |
| 18 | 4 | 57.725 | 21 8 | | | | |
| | | | | 102 | 4 | +232.256 | +36 36 |
| 137 | 3 | + 43.365 | +17 39 | 110 | 2 | 255.052 | 35 25 |
| 129 | 2 | 67.540 | 15 56 | | | | |
| 119 | 3 | 95.634 | 14 16 | 273 | 4 | +248.560 | +11 32 |
| | | | | 264 | 2 | 274.921 | 9 3 |
| 249 | 2 | + 56.579 | —15 40 | | | | |
| 247 | 1 | 74.033 | 14 40 | 57 | 4 | +255.288 | +13 56 |
| | | | | 41 | 1 | 278.957 | 10 27 |
| 61 | 1 | + 91.934 | +24 32 | | | | |
| 66 | 4 | 118.799 | 23 58 | 68 | 3 | +254.062 | +13 0 |
| | | | | 43 | 1 | 278.957 | 10 35 |

is short, by the disturbed motion, becomes quite obvious in longer intervals, as, for example, in an entire revolution. The annexed Table A contains the latitudes of those spots which reappeared on the eastern limb of the sun's disc after they had disappeared on the western. All the spots, the identity of which could be made out, have been inserted; none excluded. The numbers (which are the means of the single determinations during one appearance, corresponding to the mean epochs) show without exception a decrease in latitude, the unique instance of the increase of one minute being entirely overthrown by the amount of the probable error.

A general proper motion of the spots towards the equator being recognized, the question is raised naturally: Have they any motion also in longitude? and in what sense? to the east or to the west? The solution of this question is intimately connected with the determination of the time of rotation. For it is clear, if all the spots had an *equal* proper motion in longitude, the time of the sun's rotation, since it is deduced from the spots, would be wrong. If the spots move by a certain amount to the west, the sun's rotation will be found too great exactly by that amount; if to the east, it will be too small. In other words, it is the time of rotation of the spots which results, and not that of the sun itself. By employing then the same value in the comparison of observations made at two different epochs, the spot will appear to have been at rest, while it really has changed its place. If the general motion in longitude differs as to its amount for several spots, then a time of rotation will be derived from them, which includes the *average* general motion. Thus the value $25^d.652$, which I have given before, and which is made use of for the longitudes in the map, is affected by the average general motion of all the spots observed more than once. By means of this average value of the time of rotation, now, the successive places leave differences so significant that there can be no doubt of a very considerable motion parallel to the equator. The displacements in longitude seem even far more considerable than those in latitude. The annexed Table B gives some examples. Whether there be a common motion, and in what sense, cannot be decided in the present state of our knowledge of the sun's rotation. According to the mode in which this latter is established, the sum of the positive differences always will equal the sum of the negative, whatever be the amount of motion in common, as the

## TABLE B.

*Table exhibiting the proper Motion of some Spots in Heliographic Longitude.*

| Epoch. | Longitude. |
|---|---|
| **No. 6 (—27°).** | |
| d. | ° ′ |
| —110.042 | 6 50 |
| 109.043 | 6 12 |
| 108.073 | 5 56 |
| 103.987 | 6 57 |
| 102.944 | 8 8 |
| **No. 9 (+21°).** | |
| +55.023 | 7 58 |
| 58.134 | 8 57 |
| 60.018 | 9 5 |
| 62.966 | 9 28 |
| **No. 17 (—26°).** | |
| —110.042 | 11 9 |
| 109.043 | 12 55 |
| 108.073 | 12 49 |
| 103.987 | 14 29 |
| 102.944 | 15 9 |
| **No. 32 (+19°).** | |
| +58.134 | 25 27 |
| 60.018 | 24 9 |
| 62.966 | 22 45 |
| **No. 44 (+24°).** | |
| +167.023 | 38 2 |
| 170.028 | 39 44 |
| 172.019 | 41 17 |
| 174.031 | 42 52 |
| **No. 53 (—16°).** | |
| +194.152 | 55 5 |
| 196.956 | 52 25 |
| 199.028 | 50 9 |
| 201.043 | 50 42 |
| 203.023 | 49 56 |
| **No. 67 (+29°).** | |
| +6.983 | 58 41 |
| 8.015 | 60 8 |
| 9.022 | 61 13 |
| 9.989 | 62 7 |
| 11.013 | 63 25 |
| **No. 72 (+14°).** | |
| d. | ° ′ |
| +113.027 | 68 21 |
| 115.033 | 66 2 |
| 118.201 | 64 48 |
| 119.938 | 64 57 |
| 122.025 | 64 54 |
| **No. 81 (+29°).** | |
| +113.027 | 73 28 |
| 115.033 | 73 27 |
| 118.201 | 75 10 |
| 119.938 | 75 53 |
| 122.025 | 76 27 |
| 124.081 | 77 56 |
| **No. 90 (+11°).** | |
| —24.100 | 91 21 |
| 22.044 | 92 10 |
| 20.996 | 92 47 |
| 19.991 | 89 43 |
| 17.990 | 88 4 |
| **No. 105 (+12°).** | |
| —77.037 | 116 28 |
| 74.940 | 114 48 |
| 73.861 | 113 19 |
| **No. 113 (+38°).** | |
| +226.148 | 115 58 |
| 228.036 | 117 58 |
| 231.032 | 120 46 |
| 233.916 | 122 26 |
| 236.041 | 125 19 |
| 238.113 | 127 22 |
| **No. 124 (+17°).** | |
| +91.934 | 130 39 |
| 95.025 | 129 57 |
| 99.942 | 127 18 |
| **No. 130 (—19°).** | |
| +119.938 | 136 39 |
| 122.025 | 135 45 |
| 124.081 | 135 9 |
| 126.087 | 134 24 |
| **No. 144 (+20°).** | |
| d. | ° ′ |
| —99.828 | 163 42 |
| 98.963 | 163 52 |
| 97.842 | 162 11 |
| 96.103 | 160 28 |
| 93.169 | 160 31 |
| 91.120 | 159 32 |
| **No. 158 (+28°).** | |
| +258.965 | 194 27 |
| 263.014 | 195 10 |
| 266.024 | 195 25 |
| 270.885 | 196 13 |
| **No. 204 (—28°).** | |
| —38.075 | 251 44 |
| 35.113 | 251 42 |
| 34.066 | 252 52 |
| 32.884 | 252 53 |
| 31.090 | 253 35 |
| 29.086 | 254 58 |
| **No. 219 (+19°).** | |
| +238.113 | 269 54 |
| 241.026 | 266 14 |
| 244.411 | 264 29 |
| **No. 242 (—16°).** | |
| +101.021 | 292 59 |
| 103.026 | 291 34 |
| 106.124 | 291 10 |
| 110.142 | 289 11 |
| 113.027 | 289 39 |
| **No. 275 (+25°).** | |
| +24.960 | 328 26 |
| 27.020 | 329 9 |
| 28.084 | 329 29 |
| 30.902 | 330 43 |
| **No. 286 (—22°).** | |
| —86.029 | 360 16 |
| 84.081 | 358 30 |
| 83.074 | 357 39 |
| 81.089 | 357 16 |

greater movements will show an excess, the slower ones a defect, according to phoronomical principles. Nevertheless, there are some reasons which make me incline to the opinion, that the general direction of the movement is towards the *west*. Farther on, I shall return to this question; but in this place, the following observation may be made, namely, that a new spot bursts out almost always to the *east* of an older one, very seldom to the west. Since it is of some interest, the linear velocity has been computed for some of the spots which seemed imbued with a somewhat considerable motion (as on the annexed Table C). Here are velocities up to between 300 and 400 miles the hour, which is not so extraordinary, considering that the sun's diameter is 112 times that of the earth, and that the strongest hurricanes on the earth are supposed to possess a velocity of 120 miles an hour. For the sake of comparison, it may be mentioned that the velocity of rotation of a point at the sun's equator is between four and five times as great as of a point at the earth's equator; or as the latter is nearly 900 miles, the former is about 4,000 miles, the hour.

TABLE C.

*Some of the greater Absolute Velocities per hour of Solar Spots observed in Geographical Miles.*

| Spot. | Velocity. | Spot. | Velocity. |
|---|---|---|---|
| No. 12 | 20 | No. 273 | 109 |
| 232 | 29 | 144 | 129 |
| 215 | 43 | 230 | 129 |
| 202 | 57 | 17 | 132 |
| 22 | 62 | 82 | 153 |
| 118 | 63 | 286 | 168 |
| 132 | 73 | 95 | 169 |
| 53 | 75 | 113 | 207 |
| 242 | 84 | 35 | 222 |
| 19 | 92 | 88 | 238 |
| 204 | 98 | 90 | 261 |
| 81 | 102 | 67 | 277 |
| 66 | 106 | 219 | 366 |

The second fact which I wish to draw attention to, results by combining together the heliographic positions of different spots, and may be pronounced, for the present, in the following thesis: —

*In certain localities of the solar surface, the spots arise more frequently than in others.*

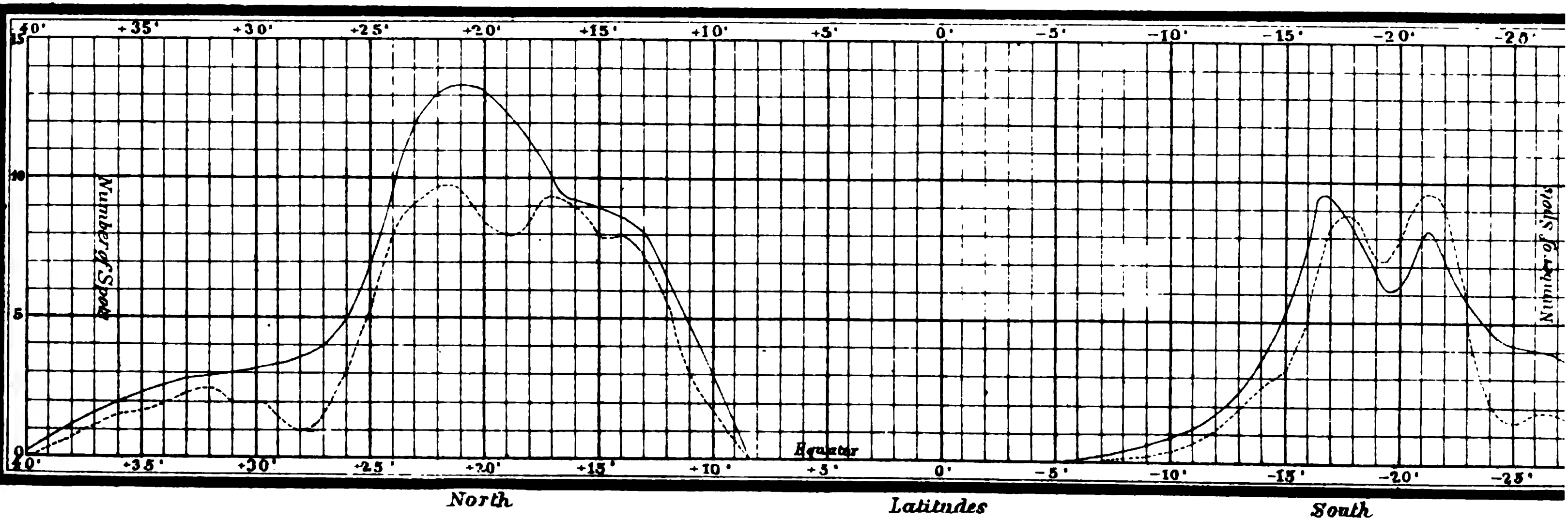
A glance upon the map shows immediately that the spots are arranged in two girdles or belts, one to each side of the equator.

This observation is not entirely new. Already Galileo had stated, that all the spots are found within an equatorial zone, the limits of which he fixed at 29°. The Jesuit Scheiner extended these limits to 30°; Messier, to 31°; Lalande, Délambre, and Méchain, to 40°; Laugier, to 41°, north and south. The remark, that the neighborhood of the equator itself is barren of spots, is of a more recent date. I see that Sir John Herschel, in his "Cape Observations," has come to a similar conclusion. Still, this region, too, is not entirely destitute of the capability of producing spots. In March, 1845, I saw some so near to the equator as 3°. But these are rather rare. In regard to the outer limits of the zone, perhaps the same may be said. By Lahire, a spot is related in 70° latitude. I observed one during several days in 50° 24′, and a remarkable facula as high up as 67°. Of the northern spots, inserted in the map, the greatest number is near to the parallel of 21°; of the southern, the greatest number is near to 17°. Here it is proper to make a distinction between *individual* spots, and *systems* or groups of spots. The spots forming a system show clearly an identical perturbation generating them in the same moment. The relative frequency in different parallels of latitude of the individual spots, as well as of the systems of spots, is represented by the curves in the annexed drawing. (Plate I.)

The establishing of *both* the co-ordinates of some fixed points as particularly productive of spots, is certainly of the greatest importance. The observations of thirteen months have shown themselves insufficient to be decisive as to the positions in longitude, though they give some intimations. The great obstacle is the uncertainty about the time of rotation, as including the proper motion in longitude. Observations continued during four or five years, and duly computed, probably would carry us a considerable step farther in this research, and consequently nearer to the true philosophy of the sun's nature. At all events, it is reasonable to suppose that the proper motion is only small in proportion to the rotary motion, so that the latter may be assumed to be right at least *approximately*. With this assumption, my computations give several instances of spots breaking out at *nearly* the same place after intervals of two and three hundred days, whilst in the intermediate time that place was plain and smooth like the rest of the sun's surface, not indicating any sign of disturbance. Avoiding, for obvious reasons, those parallels where the appearances are more condensed, I wish to point out as examples:

Plate 1

Curves showing the relative frequency of Spots in different heliographical Latitudes as observed in the years 1845-46.




Note. The dotted Curve shows the double number of Systems of Spots.

| | | | | |
|---|---|---|---|---|
| 280° | long. | and | +30° | lat. |
| 200° | " | " | +12° | " |
| 115° | " | " | +35° | " |
| 15° | " | " | —28° | " |

In order to justify the assumption, that our knowledge of the time of rotation cannot be very much out of the way, and that, of course, the proper motion of the spots can be but a small fraction of the rotary motion, I may mention the results obtained by two modern philosophers, who attempted to derive the time of the sun's rotation from observations of terrestrial temperatures. The value deduced from the long series of Innsbruck and Paris temperatures by Professor Nervander, of Helsingfors, is 27.26 days for the synodical, or 25.367 for the tropical revolution. Mr. Buys-Ballot, in Utrecht, in the same manner making use of the Belgian and other thermometrical observations, gives 27.692 days for the synodical, which would be 25.742 for the sidereal revolution.* I made some trials, to arrive at a direct conclusion of the rotation by other ways, which, for a longer series of observations, will be found effective. One is based upon the similitude of certain figures of the spots when they are first outbursting. Among these figures is an elliptic arrangement not uncommon, and two pair of those observed by me may well be considered as arisen in the same locality. A second way would be precisely by the assumption of the identity of those places, which I indicated before. But their number is still too small, and the uncertainty deriving from the extent of those localities too great, for deriving from them any exact result.

After having exposed several facts, which result from the numerical investigation of measurements, I may now relate briefly some telescopic observations, one of which, favored by the beautiful sky of Naples, is worthy the particular attention of other observers. In order to make better understood this phenomenon, I ought to trace shortly the biography of spots, such as on the whole I have noted it in the suc-

* These two results differ to about the same amount as the determinations by means of spots. The mean value of Delambre's and Lalande's researches is 25.021 days; Laugier found from 29 spots 25.34 days, the particular spots varying from 24.28 to 26.23 days; Dr. Böhm formed equations of condition for 13 spots, which gave 25.821 with a probable error of only 0.024 days. The value which I have adopted as a preliminary one, from 286 spots, 25.652 days, is intermediate between all these different determinations.

cessive stages of their appearance. The spots arise from insensible points, so that the exact moment of their origin cannot be stated; but very rapidly they grow in the beginning, and almost always in less than a day they arrive at their maximum of size. Then they are stationary, I would say in the vigorous epoch of their life, with a well defined penumbra, of regular and rather simple shape. So they sustain themselves for ten, twenty, and some even for fifty days. Then the notches of the margin, which, seen with a high magnifying power, always appears somewhat serrate, grow deeper, to such a degree that the penumbra in some parts becomes interrupted by straight and narrow luminous tracts; — already the period of decadence is approaching. This begins with the following highly interesting phenomenon. Two of the notches from opposite sides step forward into the area, overroofing even a part of the nucleus; and suddenly from their prominent points flashes go out, meeting each other on their way, hanging together for a moment, then breaking off and receding to their points of starting. Soon this electric play begins anew, and continues for a few minutes, ending finally with the connection of the two notches, thus establishing a bridge, and dividing the spot in two parts. Only once I had the fortune to witness the occurrence between *three* advanced points. Here, from the point *A* a flash proceeded towards *B*, which sent forth a ray to meet the former, when this had arrived very near. Soon this seemed saturated, and was suddenly repelled; however, it did not retire, but bent with a rapid swing towards *C*; then again, in the same manner, as by repulsion and attraction, it returned to *B*, and after having oscillated thus for several times, *A* adhered at last permanently to *B*. The flashes proceeded with great speed, but not so that the eye might not follow them distinctly. By an estimation of time and the known dimension of space traversed, at least an *under* limit of the velocity may be found; thus I compute this velocity to be not less than two hundred millions of metres (or about one hundred thousand miles) in a second. The process described is accomplished in the higher photosphere, and seems not at all to affect the lower or dark atmosphere. With it a second, or rather third, period in the spot's life has begun, that of dissolution, which lasts sometimes for ten or twenty days; during which time the components are again subdivided, whilst the other parts of the luminous margin too are pressing, diminishing, and finally over-

casting the whole, — thus ending the ephemeral existence of the spot. Rather a good chance is required for observing the remarkable phenomenon which introduces the covering process, since it is achieved in a few minutes, and it demands, moreover, a perfectly calm atmosphere, in order not to be confounded with a kind of scintillation, which is perceived very often in the spots, especially with fatigued eyes. The observer ought to watch for it, under otherwise favorable atmospherical circumstances, when a large and ten or twenty days' old spot begins to show strong indentations on its margin.

In the foregoing exposition I have avoided carefully all theoretical speculations and hypotheses. I have brought before you the facts simply as they resulted from observations combined by vigorous numerical computations. However insignificant these single results may appear, still they may lead to some important consequences relative to our knowledge of the nature of the sun. And as the method generally employed in natural philosophy consists in building upon a few facts a hypothesis as to the cause, which hypothesis then, by other facts, ought to be tried, and either rejected or confirmed, thus also to the astronomer it may be permitted, in an object which, until now, was rather more physical, than within the reach of quantitative determination.

At present there is no more any doubt about the view of Herschel (or rather Wilson) with regard to the constitution of the sun in general. Above the solid and opaque nucleus rises the atmosphere, of a nature perhaps similar to ours; this again is surrounded by a second atmosphere, luminous, and very thin. The spots are openings in both the atmospheres, leaving visible the dark solar body; the penumbra is the limb of the lower atmosphere. But now, with regard to the origin of the spots, Herschel seems to have inclined to an idea which is neither natural nor corresponding to the phenomena. According to him, the atmosphere is set in strong motion, by a cause, which he does not define nearer, is then thrown against high mountains, and thus the openings in the luminous matter are produced. This idea is indeed a little strange; and it seems to have been abandoned by modern philosophers, though without advancing any other theory in its place. All the facts of observation have impressed me strongly with the supposition, that on the surface of the solar body something exists similar to *volcanoes*, breaking out and emitting gaseous matter,

in a manner similar to the terrestrial volcanoes. These gases pass easily and speedily through the lower or dark atmosphere, until they arrive at the photosphere. Of this we have nothing in the least degree analogous upon our planet; but it appeared to me, under all circumstances, to possess in a high degree the propriety of viscosity. This viscosity at first opposes the gases, and faculæ are formed. But the gases succeed in overcoming the coherency, breaking the photosphere from beneath, usually first in numerous small points, which very soon become larger, as in the mean time the gaseous matter had collected, now bursting out with greater elasticity. These gases really have been seen; they have been observed outside of the photosphere; they are identical with the *rosy light* in the total eclipses of the sun. Especially the eclipse of July, 1851, has left no doubt, as well about the cloudy nature of this light as about its connection with faculæ and spots. Are the purple-colored ridges, which sometimes have been seen on the dark ground of the spots, perhaps also nothing else than the gases elevated above the photosphere, illuminated, and seen by projection upon the dark nucleus? With a very clear sky, the bottom of the larger spots appears never black, but always brownish or purplish, the outlines of the ridges widened, less distinct, outwashed, and the ridges themselves resemble then stronger colored plots. The gaseous exhalations explain completely the appearances of the faculæ, inflated bubbles covered by the viscous luminous matter, always preceding the outbreak of a spot, surrounding it in its first stage, but then disappearing. When the gases are effecting their escape, the luminous matter is pressed aside; hence the removal of a neighboring spot, agreeably to observation. The very sudden increase after the first opening is made, the then following stationary size, the reopening of spots nearly closed by the covering process, are necessary consequences of the emanation of elastic matters. The gases start from the surface of the nucleus impressed with the velocity of rotation corresponding to that point; in ascending to higher regions, where the velocity of rotation is greater, they remain behind to the west; on reaching the photosphere, they are opposed by the viscous tenacity of the latter, by overpowering which they lose a part of their vertical velocity, and press towards the west, communicating this direction of motion to the luminous matter surrounding the spot, and of course to the spot itself. The observation I

have before made, namely, that a new spot breaks forth in most cases on the *east* side of an older one, is now accounted for by a repeated eruption of the volcano, after it had been reposing for a short lapse of time, during which the older opening has advanced towards the west. The volcanoes are situated principally in two zones or belts, on both sides of the equator, to which phenomenon geologists will find an analogy in the greater mountain chains upon our globe; hence the frequency of spots on certain parallels. If this theory of volcanic eruptions which I have dared to advance shall be confirmed, especially by the establishment of certain fixed eruptive points in longitude, then, with some confidence, we may compare the moon to a country of extinguished volcanoes, our planet to a volcano languishing in eruptions, and the sun to the seat of volcanoes in a *prodigious* state of activity.

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5. METHOD OF DETERMINING LONGITUDES BY OCCULTATIONS OF THE PLEIADES. By PROFESSOR BENJAMIN PEIRCE, of Cambridge. (Communicated by Permission of PROFESSOR A. D. BACHE, Superintendent of the Coast Survey.)

1. THE determination of longitudes by occultations of the stars appears to be the most exact of all astronomical methods for such determinations, and deserves therefore a most careful examination, in order to ascertain the greatest degree of accuracy of which it is susceptible, and the surest method of securing such accuracy. The sources of error are partly those of observation, and partly those of theory. The errors arising from observation are of two classes; first, there are those which are special to the observations of the occultations; and, secondly, there are those which are general and inseparable from the theoretical defects.

2. The probable error of the direct observation of an occultation has been investigated by Commander C. H. Davis, from simultaneous observations made by different observers at the same place. From his researches, which were communicated to the Association at Washington, it appears that this probable error is about a fifth of a second of time, so that the ultimate probable error of the mean of this class

of observations cannot exceed a twentieth of a second of time. If, therefore, the theoretical defects can be eliminated by proper precautions and a sufficient accumulation of observations, longitudes may be obtained by this method, of which the probable error shall be decidedly inferior to a tenth of a second of time.

3. It is obvious that, with the present uncertainty of the lunar theory, isolated occultations cannot approach this degree of accuracy in the determination of longitudes. But well-determined groups of stars are essential to correct the lunar elements and rectify the places of the stars themselves. The present plan is to carry out the suggestions of Walker, in his report to the Superintendent published in 1851, by combining all the known observations of occultations of the Pleiades, and using them to correct the lunar semidiameter, the mutual positions and changes of position of the stars of this group, to test and correct the formulæ for lunar parallax, to determine the irregularities of the moon's limb, and, finally, to correct the longitudes of the places of observation.

4. Of the various forms of computation which might be adopted, I have selected that which is derived from the stereographic projection of the sphere, in which the star Alcyone *is the pole of projection.* The advantages of the stereographic projection consist in the circularity of the projections of all the spherical circles, so that the moon is represented by a circle on the plane of projection. The advantage of placing the pole of projection at the star Alcyone is, that the distances and relative positions of the projected places of the stars are only affected by the differences of their proper motions, and the small differential effects of aberration. There may be a doubt whether the somewhat greater simplicity of the formulæ, in the case in which the pole of projection coincides with that of the celestial equator, should not cause this form of projection to be preferred; and it may be advisable, in order to insure accuracy, to conduct the computations, independently, by each method.

5. As the basis of computation, the places of the stars have been taken from Bessel's investigations, which are contained in the first volume of his *Astronomische Untersuchungen*, in the article entitled *Beobachtungen Verschiedener Sterne der Plejaden.* The places of the moon are taken from the Nautical Almanac, or from the "Tables of the Moon," constructed for the American Ephemeris, and the

moon's parallax and semidiameter from the "Tables of the Moon's Parallax constructed from Walker's and Adams's Formulæ for the Use of the American Ephemeris and Nautical Almanac."

6. The following are the formulæ for the computation of the stereographic projections: —

Let $\alpha =$ the right ascension of Alcyone;
$\beta =$ the declination of Alcyone;
$\alpha' =$ the right ascension of another star or of the moon's centre;
$\beta' =$ the declination of the second star or of the moon's centre;
$\Delta\alpha = \alpha' - \alpha$;
$\Delta\beta = \beta' - \beta$.

The axes of $x$ and $y$ have their origin at Alcyone, the axis of $y$ is directed to the north, and that of $x$ to the east. The co-ordinations of the star are given by the formulæ,

$$A = 1 - \sin^2 \tfrac{1}{2} \Delta\beta + \sin^2 \tfrac{1}{2} \Delta\alpha \cos\beta \cos\beta'$$
$$B \sin 1'' = \sin \Delta\alpha \cos\beta';$$
$$C \sin 1'' = \Delta\beta + 2 \sin^2 \tfrac{1}{2} \Delta\alpha \sin\beta \cos\beta';$$
$$x = \frac{B}{A};$$
$$y = \frac{C}{A}.$$

The radius of the circle, which represents the moon, is given by the formula,

$$\Sigma_2 = [1 + \tfrac{1}{4}(x^2 + y^2) \sin^2 1''] \Sigma_1,$$

in which $\Sigma_1$ is the augmented semidiameter of the moon.

The computation of $A$, $C$, and $\Sigma_2$ should be performed with the aid of the Gaussian logarithms.

7. The formulæ for the corrections of latitude for the earth's eccentricity are,

$\phi =$ the geographical latitude of the place;
$e =$ the earth's eccentricity;
$\sin\psi = e \sin\phi$;
$h = \sec\psi \cos\phi$;
$k = (1 - e^2) \sec\psi \sin\phi$.

8. The parallax of the moon in right ascension and declination, and

its augmented semidiameter, are obtained from the formulæ of Olbers, which are,

$\pi =$ the moon's equatorial horizontal parallax;
$s =$ the sidereal time at the place of observation;
$a_0 =$ the moon's tabular right ascension;
$\beta_0 =$ the moon's tabular declination;
$\Delta_\pi a = a' - a_0 =$ the parallax in right ascension;
$\Delta_\pi \beta = \beta' - \beta_0 =$ the parallax in declination;

$$P \sin 1'' = h \sin \pi \sec \beta_0;$$

$$\operatorname{tang} \Delta_\pi a = \frac{P \sin 1'' \sin (s - a_0)}{1 - P \sin 1'' \cos (s - a_0)};$$

$$\operatorname{tang} \eta = \frac{k \cos \frac{1}{2} \Delta_\pi a}{h \cos (s - a_0 - \frac{1}{2} \Delta_\pi a)};$$

$$Q \sin 1'' = \frac{k \sin \pi}{\sin \eta};$$

$$\operatorname{tang} \Delta_\pi \beta = \frac{Q \sin 1'' \sin (\beta_0 - \eta)}{1 - Q \sin 1'' \cos (\beta_0 - \eta)};$$

$$\log a = 9.435000;$$

$$\Sigma_1 = a \pi \frac{\sin (\beta' - \eta)}{\sin (\beta_0 - \eta)}.$$

9. In order to determine the equations of condition for the correcting of the lunar elements, of the places of the stars, and of the longitude of the place, let

$x_m, y_m$ denote the co-ordinates of the moon's place affected with parallax;
$x_s, y_s$, those of the star's place;
$p$, the distance of the star from the centre of the moon for the recorded instant of the observed immersion or emersion;
$\theta$, the angle which $p$ makes with the axis of $x$;
$\theta'$, the angle which the moon's apparent path, affected with parallax, makes with the axis of $x$;
$v$, the velocity of the moon for a second of time estimated in seconds of space;
$x'_m, y'_m$, the changes in the values of $x_m$ and $y_m$ for a second of time;
$\delta x_m$, the correction of $x_m$ for the instant denoted by $\tau$;
$\delta \beta_m$, the correction of the moon's declination for the instant $\tau$;
$\delta x_s$, the correction of $x_s$ for the year 1840;

$\delta \beta_{,,}$ the correction of the star's declination for the year 1840;
$\delta x'_m$, the correction of the hourly change of $x_m$;
$\delta \beta'_m$, the correction of the moon's hourly motion in declination;
$\delta x'_{,,}$ the correction of the star's annual change of $x_,$;
$\delta \beta'_,$, the correction of the star's annual proper motion in declination;
$\delta \pi$, the correction of the moon's horizontal parallax;
$\delta a$, the correction of $a$;
$\delta b$, the correction of the moon's semidiameter for irregularity of outline;
$\delta \lambda$, the correction of the western longitude of the place in seconds of time;
$\delta t$, the correction in seconds of the local time of observation for the night's work;
$t$, the time expressed in hours and decimals of an hour;
$t_{,,}$ the time in years from 1840.

The subsidiary formulæ for the determination of $p$, $v$, $\theta$, and $\theta'$ are,

$$p \cos \theta = x_, - x_m ;$$
$$p \sin \theta = y_, - y_m ;$$
$$v \cos \theta' = x'_m ;$$
$$v \sin \theta' = y'_m .$$

And the equation of condition is

$$\cos \theta \left[\delta x_, - \delta x_m + t_{,} \delta x'_, - (t - \tau)\, \delta x'_m\right] + \sin \theta \left[\delta \beta_, - \delta \beta_m + t_{,} \delta \beta'_, - (t - \tau)\, \delta \beta'_m\right] - \left[\frac{\Delta_\pi a \cos \beta_0}{\pi} \cos \theta + \frac{\Delta_\pi \beta}{\pi} \sin \theta + a\right] \delta \pi - \pi \,\delta a - \delta p - v \cos (\theta' - \theta)\, [\delta \lambda + \delta t] = \Sigma_2 - p.$$

10. In computing $x_m$ and $y_m$ by the formulæ of § 6, the apparent right ascension and declination of Alcyone must be taken for the time from the Nautical Almanac or Bessel's *Tabulæ Regiomontanæ.* The values of $x_,$ and $y_,$ must be corrected for proper motion, and also for the change in the co-ordinates arising from precession and aberration. The formulæ for the computation of these changes have been recently investigated by Dr. Peters, who has constructed tables which greatly facilitate their use.

(Dr. Peters's investigation was here presented to the Association, and also the co-ordinates of the Pleiades, computed by Mr. Webber and myself, as well as those of the values of $h$ and $k$, for all the principal observatories.)

11. The great number of corrections to be determined will prevent the success of this method, unless they are divided, with just discretion, into classes arranged for separate discussion. Thus the determination of the irregularities of the moon must be preceded by that of its mean diameter, and the proper motions of the stars cannot be corrected until the final combination of all the observations. For each night of observation, the elements of the moon's place, its parallax, and the local time, must be subjected to separate discussion, while for each period of occultation the corrections of the star's places, of the longitudes, and of the constant $a$, may be determined.

This labor will be greatly relieved by a new determination of the places of the Pleiades, and there seems to be no instrument capable of such delicate work but the heliometer. It is much to be desired, therefore, that this important instrument may be obtained for one of our observatories.

NOTE. — Dr. Armsby of Albany, who was present at the meeting, was incited by this announcement to write to Mr. Olcutt, who immediately undertook to obtain the aid of the gentlemen of Albany in providing this instrument for the Dudley Observatory of Albany. But upon submitting the matter to Mrs. Dudley, this generous lady offered to take the whole burden upon herself. By the ardent zeal of other gentlemen, aided by the generosity of another lady, Mrs. Corning, Dr. Gould was, in a few weeks, induced to go to Europe for the purpose of purchasing, for the Dudley Observatory, the Dudley Heliometer, the Corning Astronomical Clock, a meridian circle, and a prime-vertical transit instrument. The magnitude and promptness of this liberality are equally remarkable, and cannot fail to stimulate the Association to perseverance in its efforts for the advancement of science.

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## III. PHYSICS.

### 1. ON THE MODE OF TESTING BUILDING MATERIALS, AND AN ACCOUNT OF THE MARBLE USED IN THE EXTENSION OF THE UNITED STATES CAPITOL. By PROFESSOR JOSEPH HENRY, Secretary of the Smithsonian Institution.

A COMMISSION was appointed by the President of the United States in November, 1851, to examine the marbles which were offered for

the extension of the United States Capitol, which consisted of General Totten, A. J. Downing, the Commissioner of Patents, the architect, and myself. Another commission was subsequently appointed, in the early part of the year 1854, to repeat and extend some of the experiments,—the members of which were General Totten, Professor Bache, and myself.

A part of the results of the first commission were given in a report to the Secretary of the Interior, and a detailed account of the whole of the investigations of these committees will ultimately be given in full in a report to Congress, and I propose here merely to present some of the facts of general interest, or which may be of importance to those engaged in similar researches.

Though the art of building has been practised from the earliest times, and constant demands have been made, in every age, for the means of determining the best materials, yet the process of ascertaining the strength and durability of stone appears to have received but little definite scientific attention, and the commission, who have never before made this subject a special object of study, have been surprised with unforeseen difficulties at every step of their progress, and have come to the conclusion that the processes usually employed for solving these questions are still in a very unsatisfactory state.

It should be recollected, that the stone in the building is to be exposed for centuries, and that the conclusions desired are to be drawn from results produced in the course of a few weeks. Besides this, in the present state of science, we do not know all the actions to which the materials are subjected in nature, nor can we fully estimate the amount of those which are known.

The solvent power of water, which even attacks glass, must in time produce an appreciable effect on the most solid material, particularly where it contains, as the water of the atmosphere always does, carbonic acid in solution. The attrition of siliceous dusts, when blown against a building, or washed down its sides by rain, is evidently operative in wearing away the surface, though the evanescent portion removed at each time may not be indicated by the nicest balance. An examination of the basin which formerly received the water from the fountain at the western entrance of the Capitol, now deposited in the Patent Office, will convince any one of the great amount of action produced principally by water charged with carbonic acid. Again,

every flash of lightning not only generates nitric acid, — which, in solution in the rain, acts on the marble, — but also by its inductive effects at a distance produces chemical changes along the moist wall, which are at the present time beyond our means of estimating. Also the constant variations of temperature from day to day, and even from hour to hour, give rise to molecular motions which must affect the durability of the material of a building. Recent observations on the pendulum have shown that the Bunker Hill Monument is scarcely for a moment in a state of rest, but is constantly warping and bending under the influence of the varying temperature of its different sides.

Moreover, as soon as the polished surface of a building is made rough from any of the causes aforementioned, the seeds of minute lichens and mosses, which are constantly floating in the atmosphere, make it a place of repose, and by the growth and decay of the microscopic plants which spring from these, discoloration is produced, and disintegration assisted.

But perhaps the greatest source of the wearing away in a climate like ours, is that of the alternations of freezing and thawing which take place during the winter season; and though this effect must be comparatively powerful, yet, in good marble, it requires the accumulated effect of a number of years in order definitely to estimate its amount. From all these causes, the commission are convinced that the only entirely reliable means of ascertaining the comparative capability of marble to resist the weather, is to study the actual effects of the atmosphere upon it, as exhibited in buildings which for years have been exposed to these influences. Unfortunately, however, in this country, but few opportunities for applying this test are to be found. It is true some analogous information may be derived from the examination of the exposed surfaces of marble in their out-crops at the quarry; but in this case the length of time they have been exposed, and the changes of actions to which they may have been subjected during, perhaps, long geological periods, are unknown; and since different quarries may not have been exposed to the same action, they do not always afford definite data for reliable comparative estimates of durability, except where different specimens occur in the same quarry.

As we have said before, the art of testing the quality of stone for building purposes is at present in a very imperfect state; the object is to imitate the operations of nature, and at the same time to hasten

the effect by increasing the energy of the action, and, after all, the result may be deemed but as approximative, or, to a considerable degree, merely probable.

About twenty years ago an ingenious process was devised by M. Brard, which consists in saturating the stone to be tested with a solution of the sulphate of soda. In drying, this salt crystallizes and expands, thus producing an exfoliation of surface which is supposed to imitate the effect of frost. Though this process has been much relied on, and generally employed, recent investigations made by Dr. Owen lead us to doubt its perfect analogy with that of the operations of nature. He found that the results produced by the actual exposure to freezing and thawing in the air, during a portion of winter, in the case of the more porous stones, produced very different results from those obtained by the drying of the salt. It appears from his experiments, that the action of the latter is chemical as well as mechanical.

The commission, in consideration of this, have attempted to produce results on the stone by freezing and thawing by means of artificial cold and heat. This process is, however, laborious; each specimen must be inclosed in a separate box fitted with a cover, and the amount of exfoliation produced is so slight, that in good marble the operation requires to be repeated many times before reliable comparative results can be obtained. In prosecuting this part of the inquiries, unforeseen difficulties have occurred in ascertaining precisely the amount of the disintegration, and it has been found that the results are liable to be vitiated by circumstances which were not foreseen at the commencement of the inquiries.

It would seem at first sight, and the commission when they undertook the investigation were of the same opinion, that but little difficulty would be found in ascertaining the strength of the various specimens of marbles. In this, however, they were in error. The first difficulty which occurred was to procure the proper instrument for the purpose. On examining the account of that used by Rennie, and described in the Transactions of the Royal Society of London, the commission found that its construction involved too much friction to allow of definite comparative results. Friction itself has to be overcome, as well as the resistance to compression, and since it increases in proportion to the pressure, the stronger stones would appear relatively to withstand too great a compressing force.

The commission first examined an instrument — a hydraulic press — which had previously been used for experiments of this kind, but found that it was liable to the same objection as that of the machine of Rennie. They were, however, extremely fortunate subsequently in obtaining, through the politeness of Commodore Ballard, commandant of the Navy Yard, the use of an admirable instrument devised by Major Wade, late of the United States Army, and constructed under his direction, for the purpose of testing the strength of gun metals. This instrument consists of a compound lever, the several fulcra of which are knife-edges, opposed to hardened steel surfaces. The commission verified the delicacy and accuracy of the indications of this instrument by actual weighing, and found, in accordance with the description of Major Wade, the equilibrium was produced by *one* pound in opposition to *two hundred*. In the use of this instrument the commission were much indebted to the experience and scientific knowledge of Lieutenant Dahlgreen, of the Navy Yard, and to the liberality with which all the appliances of that important public establishment were put at their disposal.

Specimens of the different samples of marble were prepared in the form of cubes of one inch and a half in dimension, and consequently exhibiting a base of two and a quarter square inches. These were dressed by ordinary workmen with the use of a square, and the opposite sides made as nearly parallel as possible by grinding by hand on a flat surface. They were then placed between two thick steel plates, and, in order to insure an equality of pressure, independent of any want of perfect parallelism and flatness on the two opposite surfaces, a thin plate of lead was interposed above and below between the stone and the plates of steel. This was in accordance with a plan adopted by Rennie, and that which appears to have been used by most, if not all, of the subsequent experimenters in researches of this kind. Some doubt, however, was expressed as to the action of interposed lead, which induced a series of experiments to settle this question, when the remarkable fact was discovered, that the yielding and approximately equable pressure of the lead caused the stone to give way at about half the pressure it would sustain without such an interposition. For example, one of the cubes, precisely similar to another which withstood a pressure of upwards of 60,000 pounds when placed in immediate contact with the steel plates, gave way at about 30,000 with lead

interposed. This remarkable fact was verified in a series of experiments, embracing samples of nearly all the marbles under trial, and in no case did a single exception occur to vary the result.

The explanation of this remarkable phenomenon, now that it is known, is not difficult. The stone tends to give way by bulging out in the centre of each of its four perpendicular faces, and to form two pyramidal figures, with their apices opposed to each other at the centre of the cube, and their bases against the steel plates. In the case where rigid equable pressure is employed, as in that of the thick steel plate, all parts must give way together. But in that of a *yielding* equable pressure, as in the case of interposed lead, the stone first gives way along the lines of least resistance, and the remaining pressure must be sustained by the central portions around the vertical axis of the cube.

After this important fact was clearly determined, lead and all other interposed substances were discarded, and a method devised by which the upper and lower surfaces of the cube could be ground into perfect parellelism. This consists in the use of a rectangular iron frame, into which a row of six of the specimens could be fastened by a screw at the end. The upper and lower surfaces of this iron frame were wrought into perfect parallelism by the operation of a planing machine. The stones being fastened into this, with a small portion of the upper and lower parts projecting, the whole were ground down to a flat surface, until the iron and the face of the cubes were thus brought into a continuous plane. The frame was then turned over, and the opposite surfaces ground in like manner. Care was of course taken that the surfaces thus reduced to perfect parallelism, in order to receive the action of the machine, were parallel to the natural beds of the stone.

All the specimens tested were subjected to this process, and in their exposure to pressure were found to give concordant results. The crushing force exhibited in the subjoined table is much greater than that heretofore given for the same material.

The commission have also determined the specific gravities of the different samples submitted to their examination, and also the quantity of water which each absorbs.

They consider these determinations, and particularly that of the resistance to crushing, tests of much importance, as indicating the cohe-

sive force of the particles of the stone, and its capacity to resist most of the influences before mentioned.

The amount of water absorbed may be regarded as a measure of the antagonistic force to cohesion, which tends, in the expansion of freezing, to disintegrate the surface. In considering, however, the indication of this test, care must be taken to make the comparison between marbles of nearly the same texture, because a coarsely crystallized stone may apparently absorb a small quantity of water, while in reality the cement which unites the crystals of the same stone may absorb a much larger quantity. That this may be so was clearly established in the experiments with the coarsely crystallized marbles examined by the commission. When these were submitted to a liquid which slightly tinged the stone, the coloration was more intense around the margin of each crystal, indicating a greater amount of absorption in these portions of the surface.

The marble which was chosen for the Capitol is a dolomite, or is composed of carbonate of lime and magnesia in nearly atomic proportions. It was analyzed by Dr. Torrey of New York, and Dr. Genth of Philadelphia. According to the analysis of the former, it consists, in hundredth parts, of

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| Carbonate of lime, | 54.621 |
| Carbonate of magnesia, | 43.932 |
| Carbonate of protoxide of iron, | .365 |
| Carbonate of protoxide of manganese, | (a trace.) |
| Mica, | .472 |
| Water and loss, | .610 |

The marble is obtained from a quarry in the southeasterly part of the town of Lee, in the State of Massachusetts, and belongs to the great deposit of primitive limestone which abounds in that part of the district. It is generally white, with occasional blue veins. The structure is fine-grained. Under the microscope it exhibits fine crystals of colorless mica, and occasionally also small particles of bisulphuret of iron. Its specific gravity is 2.8620; its weight 178.87 lbs. per cubic foot; it absorbs .103 parts of an ounce per cubic inch, and its porosity is great in proportion to its power of resistance to pressure. It sustains 23,917 lbs. to the square inch. It not only absorbs water by capillary attraction, but, in common with other marbles, suffers the dif-

fusion of gases to take place through its substance. Dr. Torrey found that hydrogen and other gases, separated from each other by slices of the mineral, diffuse themselves with considerable rapidity through the partition.

This marble, soon after the workmen commenced placing it in the walls, exhibited a discoloration of a brownish hue, no trace of which appeared so long as the blocks remained exposed to the air in the stonecutter's yard. A variety of suggestions and experiments were made in regard to the cause of this remarkable phenomenon, and it was finally concluded that it was due to the previous absorption by the marble of water holding in solution a small portion of organic matter, together with the absorption of another portion of water from the mortar.

To illustrate the process, let us suppose a fine capillary tube, the lower end of it immersed in water, and of which the internal diameter is sufficiently small to allow the liquid to rise to the top, and be exposed to the atmosphere; evaporation will take place at the upper surface of the column, a new portion of water will be drawn in to supply the loss; and if this process be continued, any material which may be dissolved in the water, or mechanically mixed with it, will be found deposited at the upper orifice of the tube, or at the point of evaporation.

If, however, the lower portion of the tube be not furnished with a supply of water, the evaporation at the top will not take place, and the deposition of foreign matter will not be exhibited, even though the tube itself may be filled with water impregnated with impurities. The pores of the stones so long as the blocks remain in the yard are in the condition of the tube not supplied at its lower end with water, and consequently no current takes place through them, and the amount of evaporation is comparatively small; but when the same blocks are placed in the wall of the building, the absorbed water from the mortar at the interior surface gives the supply of the liquid necessary to carry the coloring material to the exterior surface, and deposit it at the outer orifices of the pores.

The cause of the phenomenon being known, a remedy was readily suggested, which consisted in covering the surface of the stone to be embedded in mortar with a coating of asphaltum. This remedy has apparently proved successful. The discoloration is gradually disappearing, and in time will probably be entirely imperceptible.

This marble, with many other specimens, was submitted to the freezing process fifty times in succession. It generally remained in the freezing mixture for twenty-four hours, but sometimes was frozen twice in the same day. The quantity of material lost was .00315 parts of an ounce. On these data Captain Meigs has founded an interesting calculation, which consists in determining the depth to which the exfoliation extended below the surface as the effect of its having been frozen fifty times. He found this to be very nearly the ten-thousandth part of an inch. Now, if we allow the alternations of freezing and thawing in a year on an average to be fifty times each, which, in this latitude, would be a liberal one, it would require ten thousand years for the surface of the marble to be exfoliated to the depth of one inch. This fact may be interesting to the geologist as well as the builder.

Quite a number of different varieties of marble were experimented upon. A full statement of the result of each will be given in the reports of the committees.

At the meeting of the Association at Cleveland, I made a communication on the subject of *cohesion*. The paper, however, was presented at the last hour; the facts were not fully stated, and have never been published. I will, therefore, occupy your time in briefly presenting some of the facts I then intended to communicate, and which I have since verified by further experiments and observations.

In a series of experiments made some ten years ago, I showed that the attraction for each other of the particles of a substance in a liquid form was as great as that of the same substance in a solid form. Consequently, the distinction between liquidity and solidity does not consist in a difference in the attractive power occasioned directly by he repulsion of heat; but it depends upon the perfect mobility of the atoms, or a lateral cohesion. We may explain this by assuming an incipient crystallization of atoms into molecules, and consider the first effect of heat as that of breaking down these crystals, and permitting each atom to move freely around every other. When this crystalline arrangement is perfect, and no lateral motion is allowed in the atoms, the body may be denominated perfectly rigid. We have approximately an example of this in cast-steel, in which no slipping takes place of the parts on each other, or no material elongation of the mass; and when a rupture is produced by a tensile force, a rod of

this material is broken with a transverse fracture of the same size as that of the original section of the bar. In this case every atom is separated at once from the other, and the breaking weight may be considered as a measure of the attraction of cohesion of the atoms of the metal.

The effect, however, is quite different when we attempt to pull apart a rod of lead. The atoms or molecules slip upon each other. The rod is increased in length, and diminished in thickness, until a separation is produced. Instead of lead, we may use still softer materials, such as wax, putty, &c., until at length we arrive at a substance in a liquid form. This will stand at the extremity of the scale, and between extreme rigidity on the one hand, and extreme liquidity on the other, we may find a series of substances gradually shading from one extremity to the other.

According to the views I have presented, the difference in the tenacity in steel and lead does not consist in the attractive cohesion of the atoms, but in the capability of slipping upon each other. From this view, it follows that the form of the material ought to have some effect upon its tenacity, and also that the strength of the article should depend in some degree upon the process to which it had been subjected.

For example, I have found that softer substances, in which the outer atoms have freedom of motion, while the inner ones by the pressure of those exterior are more confined, break unequally; the inner fibres, if I may so call the rows of atoms, give way first, and entirely separate, while the exterior fibres show but little indications of a change of this kind.

If a cylindrical rod of lead three quarters of an inch in diameter be turned down on a lathe in one part to about half an inch, and then be gradually broken by a force exerted in the direction of its length, it will exhibit a cylindrical hollow along its axis of half an inch in length, and at least a tenth of an inch in diameter. With substances of greater rigidity this effect is less apparent, but it exists even in iron, and the interior fibres of a rod of this metal may be entirely separated, while the outer surface presents no appearance of change.

From this it would appear that metals should never be elongated by mere stretching, but in all cases by the process of wire-drawing, or rolling. A wire or bar must always be weakened by a force which

permanently increases its length without at the same time compressing it.

Another effect of the lateral motion of the atoms of a soft heavy body, when acted upon by a percussive force with a hammer of small dimensions in comparison with the mass of metal, — for example, if a large shaft of iron be hammered with an ordinary sledge, — is a tendency to expand the surface so as to make it separate from the middle portions. The interior of the mass by its own inertia becomes as it were an anvil, between which and the hammer the exterior portions are stretched longitudinally and transversely. I here exhibit to the Association a piece of iron originally from a square bar four feet long, which has been so hammered as to produce a perforation of the whole length entirely through the axis. The bar could be seen through, as if it were the tube of a telescope.

This fact appears to me to be of great importance in a practical point of view, and may be connected with many of the lamentable accidents which have occurred in the breaking of the axles of locomotive engines. These, in all cases, ought to be formed by *rolling*, and not with the hammer.

The whole subject of the molecular constitution of matter offers a rich field for investigation, and isolated facts, which are familiar to almost every one when attentively studied, will be made to yield results alike interesting to abstract science and practical art.

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## 4. On the Effect of mingling Radiating Substances with Combustible Materials. By Professor Joseph Henry, of Washington.

I beg leave to call the attention of the Association for a few moments to a paper published by our distinguished countryman, Count Rumford, in 1802, in the first volume of the Journal of the Royal Institution of Great Britain, page 28, entitled, "Observations relative to the Means of Increasing the Quantities of Heat obtained in the Combustion of Fuel."

"It is a fact," says Count Rumford, "which has long been known,

that clay and several other incombustible substances, when mixed with sea-coal in certain proportions, cause the latter to give out more heat in its combustion than it can be made to produce when it is burnt pure or unmixed."

"It has been ascertained that when the sides and back of an open chimney fireplace, in which coals are burnt, are composed of fire-brick and heated red-hot, they throw off into the room more heat than the burning coals themselves."

"The fuel, therefore," says Count Rumford, "should be disposed or placed so as to heat the back and sides of the grate, which must always be constructed of fire-brick, and never of iron."

The vertical stratum of coal should be as thin as is consistent with perfect combustion, for a large mass of coal in the grates arrests the rays which proceed from the back and sides of the grate, and prevents their coming into the room. The grate or fireplace itself may be so contrived as to produce a proper degree of radiation, but when this is not the case, Rumford advises that the bottom of the grate be covered with a single layer of balls of fire-brick, each perfectly globular, and about two inches and a half or two and three quarters in diameter. "On this layer of balls fire is to be kindled, and in filling the grate, more balls are to be added with the coals, care being taken to mix the coals and balls well together in due proportions. If this is done, the fire will not only be very beautiful, but will send off a much greater quantity of radiant heat into the room than without them." Rumford also declares, that these balls cause the cinders to be almost entirely consumed. "The same effect is said to be produced by the mixture of coals and clay when the fuel is burnt in a close fireplace, such as an iron stove; and it is the custom in the Netherlands to mix moistened clay with the coals before they are introduced into a stove of this form."

Count Rumford gives no account, in the paper I have cited, of experiments by which the fact of the greater radiation from the balls was tested.

In reading his paper some years since, the idea occurred to me that this experiment would be worthy of repetition, with the more manageable and delicate appliances which science has of late years furnished for the use of the investigator. For this purpose I employed the thermo-electrical apparatus of Melloni, furnished with a tube like

a screen to circumscribe the field of radiation, and the result confirmed the statement of Rumford, that more heat was radiated from pieces of fire-brick mingled with the coal than from the combustible itself. The effect, however, would probably have been greater with bituminous coal. The arrangement for experimenting with coal in a fireplace was very imperfect, and I had recourse to the heat produced by the flame of a spirit-lamp, and also of a jet of hydrogen. A flame of this kind was placed before the thermo-pile, at such a distance that the needle of the galvanometer stood at 15°; the end of a platinum wire coiled into a spiral form was then introduced into the flame, and an instant increase of the radiation of heat was observed, the galvanometer advancing to 27°.

It has long been well known, that the introduction of a platinum wire into a pale flame of this character greatly increases the radiation of light, and from this experiment it is evident that the radiation of heat is increased in a like degree. After this a number of different substances were employed, such as glass, carbonate of lime, sulphate of lime, stone coal, fire clay, &c. The greatest effect appeared to be produced with pieces of carbonate of lime. The exact order, however, could not be determined without procuring a series of balls of the same diameter of these different substances. The most striking effect was produced at the very top of the flame, placing the platinum wire in the heated though almost non-luminous air, immediately above the highest point of combustion.

We cannot suppose in these experiments that the absolute amount of heat produced by the combustion of a given quantity of fuel is increased. The most probable conjecture is, that the heat of combination is converted into radiant heat, and that the flame itself is cooled in proportion as the radiation is increased. In order to bring this idea to the test of experiment, a slip of mica one fifth of an inch in breadth was introduced vertically into the lower part of the flame, while the platinum wire occupied the space just above the top. The slip of mica was placed with its flat side vertically, so as not to affect by its radiation the heat of the wire. With this arrangement the radiation of heat from the platinum was diminished. A corresponding diminution was also produced in the amount of radiant light given off, and this was readily perceptible to the sight. This effect was not due to the cooling of the flame by the conduction of the mica, since it is al-

most a non-conductor of heat, and this property was exhibited by the fact that the luminosity of the mica was confined to that part which was at the surface of the flame on either side.

It appears, therefore, from these experiments, that the introduction of a solid of great radiating power into a mass of materials in a state of combustion, increases the amount of heat thrown into the space around without increasing the absolute quantity produced by combustion, the increase of radiant heat being at the expense of the heat of combination. To give a practical illustration of the condition of the matter, if a given quantity of fuel is employed in evaporating water, by combustion, under a kettle, the useful effect would be diminished by inserting in the flame beneath or amid the combustible a better radiating substance than itself, while in the case of a fire to warm a room the effect would be directly opposite; a greater amount of heat would be thrown into the room, and less of the heat of combustion would be carried up the chimney with the escaping gas. Or to give another example. If, over a coal fire, a boiling pot be suspended, and a roasting oven before it, the introduction of a radiating material would increase the effect on the latter at the expense of that on the former.

Count Rumford has elsewhere shown, that flame is a bad conductor of heat, and in stoves and boilers heated by flame it is therefore necessary that the draft be made to impinge with considerable force upon projecting portions of the metal, in order that the greatest amount of heat may be absorbed.

If a column of heated air moves rapidly through a perpendicular stove-pipe, but a comparatively small portion of the heat will be absorbed by the metal and radiated into space around. A cylindrical stratum of non-conducting air in contact with the metal will be comparatively at rest, and through this the moving column of heated air will rapidly ascend, without communicating its heat to the metal. If, however, in this case the current of air be obstructed, and the cylindrical motion deranged by the partial close of a damper, the heat immediately around the point of obstruction will be greatly increased. With a proper arrangement of parts, I have known a dark stove-pipe immediately to become red opposite and above the damper, by the partial closing of this valve. It is probable that heat might be economized in certain cases by introducing radiating materials in flues. It should, however, be recollected, that the draft would be impeded by

the introduction of foreign materials; — 1st. On account of a direct obstruction; and, 2d. Because of the diminished temperature.

It is frequently stated, in works on chemistry, that the heating power of the flame of the compound blowpipe is very great, while its illuminating power is quite small. The truth is, however, that the radiation of heat from its flame is only commensurate with its radiation of light, and that what tends to increase the one will also increase the other.

The radiation from heated, though non-luminous air, would, from these views, appear to be small, though from meteorological considerations they would seem to be considerable.

That a solid substance increases the radiation of the heat of a flame, is an interesting fact in connection with the nature of heat itself. It would seem to show that the vibrations of gross matter are necessary to give sufficient intensity of impulse to produce the phenomena of ordinary radiant heat. Also, since the light is much increased by the same process, we would infer that, by means of the solid, the vibrations constituting heat are actually converted into those which produce the phenomena of light. The whole subject is worthy of further investigation, both in a practical and abstract scientific point of view.

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## 5. On our Sense of the Vertical and Horizontal, and on our Perception of Distance. By Lieutenant E. B. Hunt, U. S. Corps of Engineers.

Phenomena are often unobserved, or difficult of analysis, by reason of their connection with our habitual acts of consciousness. Conclusions derived from a lifelong experience of our particular conditions of existence, are practically ranked as intuitions. From infancy onwards, each waking moment's perceptions go to impress these conditions upon us as almost of absolute necessity. Our relations to space and to the earth, in their external or apparent form, are so incessantly subjects of our consciousness, that we come to regard them without special consideration or question. As a mind which has spent its habitual energies in pursuing Analytical Geometry conceives co-

ordinate axes, almost as matters of course, in every investigation, so do we all, habitually experiencing the action of gravitation, come to consider its influence, our up and down, our horizon and our general geometrical circumscription, essentially as matters of course, as intuitional perceptions, and as subjects with which reason has little concern. It is doubtless true, however, that we acquire such fundamental ideas from continuous experience, just as positively as we do any other elements of our practical knowledge.

Our ideas of the vertical and horizontal, and our sense of distance, have thus become so firmly established by our lifelong experience, that their origin, antecedent to our philosophizing exercise of reason, has become much obscured. Yet they are clearly capable of rational analysis, and their component elements can be made subjects of experiment and variation. As introductory to some observations of this nature which I have made, I will present such general views as these and other experiences have suggested.

The vertical and horizontal are our habitual co-ordinate axes of external geometrical perception. Always ourselves at the origin of co-ordinates, we refer objects seen to their respective positions, by an instantaneous perceptive location, relative to these axes. We combine a mental estimate of distance with an angular reference to the vertical and horizontal axis and plane. In the horizontal plane, our perceptive usage seems to be to refer to a central line in our field of view by angular co-ordinates. When we attempt to embrace the entire horizon in our mental sweep, we for the most part refer objects to the north and other compass lines. This, however, is a more deliberate process, and our consciousness of its steps is comparatively complete.

In the attempt to define the sources of our perception of the horizontal and vertical, two stages of causation have occurred to me as chiefly concerned in its formation.

The first of these depends on our sensibility in each part of the body and limbs to the action of gravitation, — an obscure physiological sensation of weight and pressure in a particular direction throughout the sensitive components of our bodily frame, — a sensation which is probably greatly dependent on the circulating fluids. A specific difference of sensation notifies us of the precise inclination of each portion of our system, and could we be blindfolded and sustained in any

position in the air, without any distinct consciousness of a point of suspension, we should probably still have a clear perception of the vertical at any instant. But in our ordinary position of observation, the body notifies us of the slightest variations of direction in the gravity action on each of its parts, and in the act of running down hill over rough ground, or on points of rock, it is particularly apparent how extremely delicate is this appreciation. In this exercise, our ability to combine the appreciations of ground inequalities, of our forward and downward inertia, of the force of gravity, and of that diminution of effective gravity due to the increasing rapidity of bodily descent, quite suffices to make us wonder. This diminution, as I have repeatedly observed, when starting the rapid run down hill, subtracts much from the force or shock of the footfalls. The skill of jugglers in balancing poles, &c., and that of rope-dancers in self-balancing, are illustrations of the same gravity sensibility. When we consider the unconscious skill of the fingers of the pianist or compositor, and that, in all habitual muscular acts, the tendency is to a mechanical or *quasi* involuntary action, it will not seem singular that our continuous, lifelong perceptions of gravitation in all our sensitive parts should assume an obscure or latent form in our minds, which would cause all its results or effects to seem intuitional. I ascribe that sense of the vertical within the limits of the body, whence we pass to an acquaintance with the same in the external world, entirely to this trained gravity sensibility. In the remarkable case of John Metcalf, who, though blind, was long and successfully employed in locating new roads over Derbyshire Peak, this gravity sensibility must have become particularly acute, as to this only could his skill be fundamentally ascribed.

The second causal stage in our perception of the horizontal and vertical in the external world, will be found to be chiefly visual. The testimony of the body to the direction of gravitation makes us aware of the angle between the vertical and the optic axes, by reason of the permanent organic relation between the body and these axes. In our ordinary or erect position, the mean of this angle, or its value when a perfect muscular equilibrium prevails, is a right angle, and any departure from this mean is indicated by the sensations of the various muscles, which cause the elevation or depression of the optic axes. Thus our sensations alone suffice to indicate to us the vertical and a

visual horizon perpendicular to it; and these sensations, checked and verified by a lifelong experience, acquire an accuracy of indication which would hardly be anticipated. To these sensational co-ordinates we spontaneously refer all external objects. There is very much, also, in our ordinary perspectives to suggest and indicate the true horizon. Water, as the broad sheet, the winding river, and the tumbling brook, level bottom-lands and broad prairies, continuous hill-crests and isolated knolls, either directly present horizontal planes, or give such logical indications of them as the experienced eye can readily interpret, so as to derive with much accuracy a true general horizon. Indeed, we seem never to look over an extended view without almost instantly defining, with more or less precision, our supposed horizon. Our previous experience from travelling over ground, doubtless, enters directly in our definite location of this mental horizon. Are we in a valley, we pass our horizon under most of the objects seen. Are we in a middle point of view, we pass it in a mean position. Are we on a hill-top, we pass it tangent to the general sweep of the landscape. Thus experience is made to check and qualify the sensational indications, and we fix our horizon by a compound act of sensation and judgment from past experiences.

In our mental estimate of distance, which we habitually make for all objects seen in perspective, there is doubtless a kindred combination of sensational and reflective elements. Sensation gives us a direct measure of distance for objects near at hand, while for remote objects the element of judgment enters. Our normal vision being binocular, the distance between the optical centres of the two eyes becomes a base line of constant length, to which all external distances are referred with a precision constantly decreasing, both outwards and inwards from the interior limit of distinct vision. The convergence of the optic axes on each external object is a direct result of voluntary muscular action, and its particular value is indicated by a specific sensation in the eyeball muscles. Thus the third dimension of perspective is directly represented by a sensation connected with the perceiving eyes, and adjacent distances are referred, by a real triangulation, to the interocular base line. Being thus sensationally advised of the distances of objects, as far as this base continues to be an appreciable quantity relative to the perspective distances, we have, as it were, a considerable circle around us, within which we perceive, with an

accuracy diminishing with distance, the absolute nearness or remoteness of objects. From the distances thus known, we pass on by an act of comparison or judgment to those of more remote objects, where the direct sense of distance fails us. Here, too, as for near objects, we doubtless receive some aid from the conscious focalization of the eye, and from the gradation in the clearness of definition of outlines. All our experience in appreciating distances, gained by travelling over ground and checking our estimates by actual comparison, also involuntarily comes to our aid. Our knowledge of the ordinary or absolute sizes of the various classes of objects seen will, besides, greatly affect our rational estimates of distances. Thus sensation gives a foothold on perspective distances; comparison, or a species of continued secondary triangulation, extends our visual scope; and experience brings in the judgment to correct false estimates. If this view be correct, monocular vision should be much less accurate than binocular, in the estimation of distances near at hand. The lack of the interocular base would make the process of perspective gauging almost exclusively an act of judgment. The only sensational element in the former would be that of a conscious focalization of the eye, which could hardly be of much importance. Thus, I should conclude that persons with only a single effective eye would be bad judges of distances, especially among near objects. How the fact stands, I have had no means of ascertaining.

I will now instance a few observations or experiences, tending to confirm the general views now presented.

1. In passing around a particular curve of the railroad from Worcester to Boston, I have twice observed that the whole landscape on the concave side seemed to dip strongly towards the southeast, while, from the adjoining views and the position relative to the ocean, I am satisfied that the real dip could not be nearly so great as the apparent. This I conceive to result from a composition in the body, of the centrifugal action with gravity, which inclined the sensible vertical from the curve centre, and so apparently lifted the sensible horizon, or depressed the actual ground relative to the same. This instance seems to show clearly the dependence of our horizon on our gravity sensibility.

2. From the summit of Crow Nest, the mountain just north of West Point on the west bank of the Hudson, the view southward presents

two distinct reaches of the river in the same glimpse, which seem entirely separate bodies of water, by reason of a mountain spur, which severs all apparent connection at a distance of some six miles. From the height of over twelve hundred feet, you look down on the river, not more than a mile distant, and can readily fancy this portion an elongated lake embosomed in granite hills. Some fifteen miles below, a second apparent lake is seen, and this, despite your knowledge that it is a lower part of the same river, seems elevated above the water beneath you, by perhaps two hundred and fifty feet. This illusion is due, I conceive, to a dip in the apparent southern horizon, caused by our not appreciating the elevation of our point of view relative to the hill ranges over which we look, and so passing our horizon too low among the South Highland peaks. The boldness of the south face of Crow Nest hides that side from view when on the top, and so makes us think the summit of view lower than it really is. Indeed, from a point some two hundred feet lower on the river face, the height above the river seems greater than from the summit, probably because you there see the whole connecting slope. Thus in passing our visual horizon as a kind of general tangent plane, we give it a south dip which seems to lift the distant water. This illustrates the power of our general visual habit over our gravity sensibility and our distinct knowledge.

3. From Jones's Hill, which forms the west bank of that Sleepy Hollow where the exemplary Ichabod Crane achieved immortal fame, the west view embraces a general slope of three fourths of a mile to the Hudson, then the broad Tappan Sea, and the west bank beyond, half palisades and half highlands. On a quiet afternoon of the last year, I there saw a thick fog so drape the west bank as wholly to hide it from view, yet leaving the east bank and about half of the river in full, clear sight. The fog looked extremely sky-like, and shut down in a clear line on the water. When I simply looked sensationally on this scene, the lower fog-line on the water seemed like a distant water horizon, and all above seemed but a cloudy sky. So strong was this impression, as not to be essentially impaired by seeing, half buried in the fog, the sails of a river sloop, which looked as if resting in the cloud-sky. This illusion seemed to lift the hill on which I stood to a height greatly exceeding its actual elevation. The strong likeness of the fog-boundary to a sea-horizon rotated the apparent horizon so as

to make it dip much below the real one towards the west, thus overcoming both my gravity sensibility and a familiar knowledge of the locality.

4. A few weeks since, in the early morning, when standing on the bow of a sail-boat in Newport harbor, I observed, during a thick fog, a singular apparent distortion of the water surface. The boat seemed to rest in a bowl or hollow of water, some four rods in radius. This bowl seemed bounded by a gently curved swell, which ran tangent to the apparent remote horizon. Thus the water around me seemed some four or five feet lower than the horizon water. This appearance I suppose to have resulted from the fog-line along the water looking like a dim distant horizon, and thus bringing the apparent limiting horizon-circle much too near. This would make the apparent horizon dip below the true, and would thus give a false apparent level to the water as far in as to that point where in looking down on it the true level could be distinctly seen. The true and illusive levels seemed joined by a curved swell, the curve evidently depending on the height of the eye and the density of the fog. This observation, like the preceding, illustrates the power of our idea of a water-horizon.

5. If we observe the moon when a little above the horizon, we can prove, by the simple act of shading with the hand all objects below the moon, that its apparent enlargement is in great part caused by our perception of intervening objects, magnifying our idea of its distance. The disc thus seen isolated over the forefinger seems at once to undergo a striking contraction in apparent size. On dropping the hand, the moon seems again rapidly to enlarge, as intervening objects are seen. This masking of the terrestrial horizon does not, I think, reduce the apparent size quite to that of the meridian moon, but it does not lack much of this result. It may be observed, too, that where we see the sun or moon through a forest, especially when travelling in a railroad car, they seem remarkably dilated, and when we are flitting along in a train they seem to be bounding along a parallel road, some miles off, like monstrous fire-balls. The great number of intervening branches and trunks is obviously the direct cause of this illusion. This reasoning applies directly to explaining the apparently ellipsoidal form of the sky dome. Seeing along the ground many objects on which the binocular or perspective sensibility fastens to elaborate

the sense of distance, the horizontal axes become much elongated in appearance, while the vertical axis, having no intervening objects to aid in its apprehension, is seemingly shortened. That the cause suggested by Euler, or the greater absorption of light by its more oblique transit through the strata of vapor near the horizon, may aid this effect, is highly probable.

6. I was once of a party to observe Saturn through the West Point equatorial, when the several persons observing, on stating their impressions of the planet's apparent size, were found to range in their estimates between the size of an orange and that of a cart-wheel. In this case the lack of all perspective aids makes the visual angle the sole index of size, except perhaps the obscure sense of focalization in the eye, for the vision of instrumental pencils, when not parallel in their final emergence. Hence the utter vagueness of all estimates of apparent size, which must depend on a baseless imagination as to the distance of the object.

7. In sailing on Boston harbor, I have twice seen the phenomena of diverging and converging rays, or what is commonly called "the sun drawing water," both towards the sun in the west and towards the point symmetrically below the horizon in the east. Clear as it rationally was, that these two ray systems were but the opposite perspective views of the same parallel beams of light through the air, I could not by any effort make them seem so sensationally. The opposite ray systems would not blend and look connected. The visual thinning of each beam near the perpendicular made the connection wholly invisible, and so completed the illusory projection of the beams on the sky-dome. Hence, too, an apparent widening of each beam, as it receded from the sun or the opposite point of convergence. This whole appearance is an instance of the complete subjection of the mental to the apparent or pictorial.

8. The decided power of the two eyes to determine visible distances by the convergence of their axes was strikingly shown, in observing from within a room in New York the reflection of a gas-burner globe from the street window, during the decline of daylight. When looking with both eyes, this reflection seemed established firmly just by a branch of a street tree, some ten feet outside the window. By shifting position, this branch seemed to pierce the globe, to be within or without it, all strictly according to distance. But on closing one

eye, I found it easy to transfer the image entirely across the street, by a mere exercise of imagination. When using but one eye, the rigid stability of the binocular image was entirely gone, and the apparent distance seemed almost to become the obedient subject of direct volition.

9. If, in looking over a landscape, we bring the line of the two eyes into a vertical position, by lying down on the ground or otherwise, the scene will be found to undergo some remarkable changes. Hills will seem to recede into the distance, and thus become mountains. The perspective will be found to lose much of its relief, and we shall rather seem to be looking at a picture on a huge panoramic canvas, than on an actual receding perspective. If we observe thus steadily for some time, our sense of the horizon becomes much impaired, and a strange whimsicality of aspect results. In so looking over a sheet of water from three to twenty miles in breadth, I have noticed, not only that all the opposite banks seem about equally remote, but that there was the same apparent hollowing of the near water as mentioned in the case of fog on the water, especially in the line of the nearest opposite land. By bringing both eyes into the same vertical, the interocular base evidently becomes nullified for distance-gauging in the horizontal plane. Hence a loss of discrimination in these distances, and a general averaging in our estimation, which removes the near objects and so causes the apparent hollowing of the water. Objects seem to recede to one general cylinder around you, and the perspective perception is exceedingly impaired. The case thus becomes almost one of monocular vision. The study of these changes in scenery by a simple rotation of our interocular base, is highly interesting and attractive. It shows not only the influence of this base in forming our perspective distribution of distances, but that our sense of the horizon is very dependent for its firmness and precision on our gravity sensibility in the ordinary erect position.

Various other facts illustrative of the general views presented might be instanced, but the above must now suffice.

## 6. Improvements in the Electric Telegraph, whereby two or more Terminal Stations can make Simultaneous Use of the same Wire. By Moses G. Farmer, of Boston.

It is well known that there are two principal systems of Electric Telegraph in use in this country, commonly known as the "Morse" and "House" systems.

The Morse system communicates intelligence through electro-magnetic apparatus, by the operation of breaking and closing an electric circuit at unequal intervals of time.

The House system, by means of electro-magnetic and other apparatus, transmits information by means of a type or letter wheel, so as to exhibit or print any particular letter at pleasure, which is easily done by appropriate mechanism.

Any number of machines, of either kind, may receive intelligence simultaneously in different parts of an electric circuit, but only one of the machines can be employed at one and the same time in transmitting. A combination of the two systems, however, can be so arranged that the same conductor shall, for all practical purposes, serve for the simultaneous transmission of different messages, as follows.

Suppose that, at right angles to the axis of the type-wheel in the House Telegraph, a slender spring be attached; and suppose the outward extremity of this spring, as it revolves, to come into contact with twenty-eight concentrically arranged and separately insulated metallic segments; and that to each of these segments a wire is attached and connected with one pole of a complete set of the Morse apparatus, while the other pole of the Morse apparatus is in connection with the earth in the usual manner. There will then be twenty-eight Morse instruments successively brought into metallic connection with the axis of the type-wheel by its rotation, and the consequent rotation of the slender spring above mentioned.

Suppose the apparatus above described to be located in Boston, and another set, its exact counterpart, to be placed in New York; the two House machines being connected by a wire in the usual way, and having besides an additional wire supplied with a battery, and connecting the axis of the type-wheel in the Boston machine with the axis of the type-wheel of the machine in New York.

If now the two type-wheels be adjusted together, and made to revolve in the usual manner, whenever the slender springs of the two machines are simultaneously upon their similar segments, say the *A* segments, the Morse machine *a* at Boston will be in metallic connection with the Morse machine *a* in New York, by means of the common wire connecting the axes of the type-wheels, the segments, and the springs in the two machines. Thus by the synchronous revolution of the two type-wheels, the twenty-eight machines at Boston will be successively and independently in connection with the twenty-eight machines in New York once in each revolution; and could there be twenty revolutions of the type-wheels per second, each Morse machine would make almost a continuous line, which could be broken up into groups of shorter and longer lines, or fewer or more dots in a group, the same as is now done with the continuous line in the Morse system. It would perhaps not be advisable or necessary to endeavor to work as many as twenty-eight instruments by means of two wires, but that four at least can be so worked I demonstrated by actual experiment at Boston, on one of the circuits of the Fire Telegraph, June 22d, 1852, in the presence of a number of scientific gentlemen.

Whether, upon a long line of telegraph, the signal which was sent out upon say the *A* segment of one apparatus, might not arrive at the *B* segment of the other apparatus, owing to the rotation of the type-wheels, and the time necessary for the electric wave to pass the wire, is a question which I cannot answer from experiment; it undoubtedly would were the wire sufficiently long, or the rotation of the wheels sufficiently rapid, in reference to the velocity of the wave transmission; and there is no doubt that currents might be sent from the different segments, some in one direction and some in the other, and yet be received at the proper segment at the distant station. I hope to make further experiments with the apparatus shortly, the results of which may throw new light on the phenomena of transmission in the electric wave.

The above sketch embraces the principles of an invention for which letters patent were granted me, March 29th, 1853.

7. On an Index of Papers on Subjects of Mathematical and Physical Science. By Lieutenant E. B. Hunt, U. S. Corps of Engineers.

The history of science exhibits a continual tendency towards specialization. The sphere of each laborer becomes more and more limited as the area of research is expanded and distributed into well-defined specialities. The same thing is observable in scientific research, which, in the mechanical and chemical arts, is familiarized under the name of subdivision of labor. The same advantages and disadvantages of the specializing tendency are equally observable in the domains of science and of manufactures. The restriction of investigation and of industry to limited fields of exercise, has the effect to produce the highest skill within those fields, at the price of narrowness of conception and privation of power concerning all other spheres of action and research. The man whose life is spent in heading pins, becomes almost preternaturally skilful in the manipulations of that manufacture; but this man, in any other sphere of industry, is a blunderer and a bigot. So, too, the man of science who assiduously cultivates a chosen speciality becomes therein pre-eminent, but in so doing he is in great danger of losing his grasp on those generalities which transcend his particular field, and of becoming not only impotent, but bigoted, relative to those branches of research which he has not pursued. As the microscopist restricts his field, but intensifies his vision within that field, so the cultivation of a speciality withdraws into a single study the diffused powers of the original mind. The microscopist and the specialist find the same difficulty in seeing the parts in their relations to the whole.

No problem is more important to the scientific investigator, than that of rightly co-ordinating his general and special culture. If generalization too largely prevail, his life will probably be exuberant, but fruitless. If a speciality absorbs all his powers, there will be abundance of ignoble and innutritious fruit. If he knows how properly to combine the general and the special, he is likely to bear such rich and lasting fruit as has made the names of Newton and Leibnitz, Euler and Lagrange, Cuvier and Agassiz, and all of this illustrious kindred, such unfailing sources of strength. The power to generalize and the

power to specialize must coexist in the true magnate of science. Great things may be done by men strong in either, but not the greatest. Whoever neglects general culture in his eager pursuit of the special, harms his own nature. It may be said, that power in specialities can only thus be attained; that specialist devotees are essential to the progress of science; that science, like another Juggernaut, demands the sacrifice of the man himself to his chosen pursuit. Whoever thus reasons has already sacrificed his humanity to his speciality, and is but shouting the praises of Brahma. Nor is it easy to adopt a theory of scientific castes which would make of the specialists a lower and necessary grade, whose business it is to gather materials for the generalizing noble to arrange in their true order around some latent principle which he alone is privileged to see. That some minds are thus noble by nature and by training is certain enough, but it is hard to believe that many who could be of any assistance as specialists cannot also do some part, however small, as the generalizers of their own field and of its relations to others.

The present age of science may with great propriety be called *the monographic age*. We have reached that period when every subdivision of research needs to be presented in the form of a monograph. While it is still possible for the student of any single subdivision to pursue it in all the original papers treating thereon, it is quite impossible for the investigator of a more extended area to study the contained and related subjects in their whole range of original papers. To him it is quite essential that the various subdivisions of research should each be digested, by thorough masters, of their component contributions, and brought out in their orderly, well-balanced proportions. The true, the proven, the mature, has need to be separated by adept monographers from the false, the speculative, and the crude. The contributions of many successive investigators, each tending to place their common speciality on higher ground, and to bring it out in more perfect definition, have all to be digested by one who is qualified to take the judicial point of view, and to use aright the privilege of moderns, who, as Bacon says, are the ancients of knowledge.

The model monograph is one which presents the known, substantive facts of the subject, treated in their natural order and relations, with all attainable clearness, completeness, and brevity; and which gives such an insight into the nature of all original memoirs thereon, as will

enable investigators to recur to such originals as may be important for their special purposes. Already the mathematical and physical sciences have hundreds of subjects needing to be monographed, while comparatively few are yet so adequately presented under this form as not to need either a new monograph or a revision of the old. The great number of investigators now at work; the late remarkable increase of periodical publications and memoirs, devoted to scientific subjects; the subdividing or fissiparous tendency of modern science, and its signal proclivity to annex fields of empirical practice and make them rational or strictly scientific;— these and other causes have thrown nearly all the provinces included within the present domains of science into the precise condition to need the services of well-furnished monographers.

An invaluable result of such a presentation of these subjects would be found in the aid which investigators would thus receive towards keeping up their general scientific culture, without turning too much away from their specialities. There seems no possible way by which investigators can maintain the general and the special in correct and harmonious relations, except by means of an ever-increasing expansion of their monographic aids. As the realm of knowledge goes on yearly expanding, and steadily growing more and more to exceed the possible grasp of any one mind, this need of a direct and disembarrassed presentation of all positive results, stated as far as possible in the common language of science, will become continually more pressing. It will be only by the aid of monographs of various degrees of generality that the entire domain of science can henceforth be at all surveyed by any single investigator. The narrowest fields, being first duly digested into monographs, will furnish the materials for monographs of higher generality, and from these, step by step, the ascent will be to that universal monograph which shall draw within its compass all the high generalities of the great epic cosmos in which science will attain its far-off final consummation. When physical science becomes thus organized and digested, we shall no longer be constrained to behold the ardent mind borne away by generalizing speculations beyond all basis of fact, or the far more revolting arid mind cramped within a petty speciality, and disdainfully ignoring all the vast domain of vital generalities, simply because it transcends its own dwarfed and grovelling comprehension. The only worthy type of scientific mind is that

which at the same time pursues general and special truth; which can see grand generalities underlying the minutest phenomena, and which can trace in the loftiest generalities the simple convergence of an infinite series of kindred special phenomena. The entire character of the active investigating mind of the coming generation will be much influenced by this monographic tendency and need. The extent to which we shall digest into consistent wholes the now dispersed and fragmentary materials on a long array of subjects in mathematical and physical science, will almost measure the prospective prevalence of that just union of the generalizing and the specializing powers whence alone can spring a true progress in scientific philosophy.

The views now presented are essential preliminaries to a full understanding of the bearings and workings of an index of papers on Mathematical and Physical Science. This subject is one which the naturalists have better appreciated than the mathematicians and physicists. The proof of this will be seen in that laborious work which the genius of Agassiz inaugurated, and which presents, in four octavo volumes, the titles of all known papers on natural history and geology up to its date. These titles are arranged alphabetically under the names of their authors, as is probably most convenient in the departments included. Natural history and geology, being essentially descriptive sciences, are less fitted for the classification of the subjects included than the more abstract or logical mathematical and physical sciences. A logical arrangement by subjects, at least for natural history, will scarcely now be proposed by those interested; though it is possible that Englemann's Bibliography of Natural History, which distributes authors alphabetically under a limited number of general heads, may yet serve as a model for indexing papers or memoirs in the same field.

In proceeding to examine somewhat the subject of an index of all original papers in mathematics and physics, it may be well briefly to state the circumstances which have led me to consider it. As an Assistant in the Coast Survey, I had, on several occasions, to make special investigations in which it was desirable to examine all good relevant authorities and original memoirs. How to do this was the question. To range over series after series, index after index, from beginning to end, would surely bring to light all such papers. But this is a labor of truly appalling magnitude, and not to be thought of

for each minor research. It only remained to start with such papers as I chanced to know of, or could find by the few indexes of series at my command. Then, following up all the references which could be gleaned from these sources, I could go on till they were exhausted. By that time any man of moderate patience would himself be exhausted, and indisposed to beat up for further game. Yet what guaranty is there in this process that the very best papers may not entirely escape one's knowledge? I found from experience just this result; nor do I suppose that any person can be sure of having examined all those printed papers, on a given subject of physical science, which are essential to a full comprehension of its history and development. He may find a vast deal more than he likes to read, and yet leave the best of all unknown. This is peculiarly true of those just entering on a career of research. Veterans bear in their memories some traces of the leading papers published during their lifetimes, on all subjects ever likely to enlist their activity. But the neophyte has no such aid, and does not even know how to get at the most accessible memoirs. A great loss of time, in turning over leaves for the want of specific references, is common alike to young and old. Thus, for instance, when I wished to find all the published descriptions of automatic tide-gauges, I spent a great deal of time to find what could be read in five minutes, and am by no means confident that I have seen the best description of the best foreign gauge. Every person's experience must abound in such illustrations.

I did not many times repeat this experience of time sacrifice before seeing the advantage of making this search for materials a general one, and so once for all mustering the forces which were likely to be needed. I was thus led to form the plan of a systematic examination of all the principal series of scientific memoirs and periodicals, for the purpose of extracting such titles of papers as I judged proper for a special index on subjects directly related to the various Coast Survey operations. This project met the hearty approval of the Superintendent, who has doubtless experienced its need more than any other person. He authorized my proceeding with its execution, and has furnished every encouragement. I have already examined considerably over one thousand volumes of memoirs, transactions, scientific periodicals, &c., and it is my expectation to advance this index so far as to permit its being included in the Coast Survey Report of this year

as an appendix. It will be impossible for me to exhaust the field, but fortunately a supplement can, at any time, be added, with the contributions of succeeding years, in which omissions from the first index may be supplied. This index will be arranged by means of a detailed classification under subjects, and will embrace various heads of interest to cultivators of physical science at large. Though the principle of selection is that of probable use in the Coast Survey operations, the ground covered will be of considerable extent.

Such a fragment alone, though rather laborious, I should not think worthy to bring before this Association, were it not that it has served to indicate a far more catholic plan, and one which, if executed, will prove a signal benefaction to all cultivators of mathematical and physical science. This plan is simply an extension of the one already defined, so as to arrange in one general repository all titles of papers on mathematical and physical science. The ground unoccupied by the index of Agassiz and his collaborators should all be included, so as to aggregate in the two works references to all scientific researches. Engineering, machines, chemical, mechanical, and artistic technology, would be invaluable additions, and should, if possible, all be embraced. All these titles, being duly extracted, and, when necessary, annotated, would admit of classification into several volumes, each containing a connected group of subjects, so that every investigator would find most of the references he would need in a single volume.

It was to somewhat such a shape that this plan reduced itself, when I came to confer with Professor Henry and Professor Baird of the Smithsonian Institution. In the programme of objects proposed to be accomplished by that Institution is included a project of this very character. Professor Henry, having, as he declares, found particular advantages from using the Mathematical and Physical Index arranged by that clear-minded philosopher, Dr. Thomas Young, on a somewhat similar idea, was not likely to forget this among plans for the increase and diffusion of knowledge. It is indeed a plan for rendering accessible the knowledge already recorded, and as such eminently deserves the aid of that Institution. Were the work done, and well done, the Institution would undoubtedly undertake its publication. But done it is not, and the question is how to accomplish its proper execution. Could I have commanded my own time, the performance of this task would have been a congenial labor. In spite of that precariousness of

station which is my professional prerogative, I was much inclined to this undertaking, and probably should have begun it had not the assignment of triple public duties made it simple folly to venture it. Thus, with the best intentions, I am obliged to forego this expectation, and have brought the subject here in the hope that some one, more favored by circumstances, may be induced to undertake so needful an enterprise. I will gladly lend any aid in my power to any one who is both fit and willing thus to work for the good of science. How far assistance and compensation might be allowed by the Smithsonian Institution in the execution of this plan is, of course, not for me to say. From the real value of the proposed work, and the interest felt by the Smithsonian officers in its accomplishment, it is fair to infer that no reasonable aid would be denied which the means of the Institution would authorize. Its valuable collection of memoirs and transactions would be of peculiar value in this connection.

There is one excellent suggestion for which I am indebted to Professor Baird. This is, that an index of American scientific papers would be a useful and proper beginning for such an undertaking. The exceedingly scattered and anomalous vehicles through which American investigations have reached the present time, will make this portion of the search rather peculiar, and it is on this account much more needful. In truth, we do not know the real wealth of our own science, especially those of us who are young in such pursuits. Europe, too, is in a state of deplorable ignorance relative to our investigations; — an ignorance which has considerable excuse too, — for how can we expect foreigners to ferret our science from Patent-Office or Coast-Survey Reports, or other public documents, Regents' reports, State legislative documents, or indeed from any except the standard journals and the volumes of memoirs. Thus there are very good reasons for an American index as preliminary to a general one, with which it could be regularly incorporated.

The work now proposed is certainly one of great labor. It will require several years' time, and an examination of various libraries for its completion. Our own libraries will not offer all the materials needed for its completeness. English, French, German, Dutch, Spanish, Italian, Hungarian, Russian, Swedish, and Latin series will need to be ransacked before the work is finished. A delicate exercise of judgment in accepting or rejecting titles will be required. There

will be sundry questions such as these: Shall any anonymous papers be included? Shall papers in the literary magazines be selected? Shall titles be given in full and literally, or cut down, modernized, translated, or annotated? Shall translations be included? Shall reprints into more accessible series be referred to? &c. It has been my practice to include the date in each title, and to give the limiting pages of each memoir as an indication of the fulness with which its subject is treated.

The labor of classification will be one demanding a truly cosmopolite mind. Rightly to distribute the hundreds of subjects, and always to maintain the truly logical catena of succession, will require a broad power of appreciation such as few possess. Many plans of classification might be devised, and each having some advantages. But whatever system is adopted, an alphabetical index of subjects would make it easy of practical use. This study of classification would, of itself, be a most valuable research; for I am confident that any abstract or *a priori* plan would find the materials somewhat refractory, and thus would undergo modification and amplification. The general alphabetical arrangement of titles by author's names would, I think, be quite unfit for this case. The greatest benefit of the whole plan would be in its bringing together references to all which has been written on each subject, and thus at once giving a clew to all the materials for perfect monographs. It is of far less importance in mathematics and physics to know the *who* than the *what.* But both can be sufficiently known by alphabetical arrangement of authors under subjects, and by an index of authors' names with references to all the subjects under which each has titles. Thus all the papers of any author, and all the papers on any subject, may be directly found.

I need not further enlarge on this plan. Should there be any who has capacity and courage to undertake the great enterprise indicated, further hints would be superfluous for him. Should there be several who are willing to associate their labors, each taking certain series, and so together exploring the whole, it will not be difficult to concert a general plan. The greatest difficulty of such an association would be in securing thorough co-operation and uniform execution. The means of classification would of course be by movable slips, and thus most incongruities of plan would be avoided by making the classification the work of one.

When we look at an individual labor so valuable as Poole's Index of Periodical Literature, we cannot doubt that the labor now proposed is destined erelong to enlist far greater industry and talent, and that, if seriously undertaken, it must succeed. Dr. Young's Index, contained in the volumes of his works, would afford valuable aid towards conceiving the plan, though it is very far from perfect, and of too old a date to permit the continuance of its classification without much change. The proposed index seems to be one of those undertakings which the current of events will render too indispensable not to be erelong begun. If so extended as to embrace engineering, machines, and the technology of art and manufactures, (chemistry in all its applications would of course be included,) it will become sufficiently valuable to many merely practical interests to enlist their active support. Our Patent-Office might well afford to defray all the cost of such a work, in those departments over which examinations for patents are required to be made.

If, for a moment, we conceive the result attained, and the entire compass of reference to mathematical and physical papers, brought into a systematic body under specific subject-headings, we shall better realize its value. The course of investigation on any particular subject would be made simple and direct. By yearly supplements, we might be kept informed of new papers beyond our ordinary range. The investigator would proceed to exhaust all the papers of value on any subject in hand, and would know when he was done; thus he would start thoroughly furnished for making additions to existing knowledge, instead of wasting his strength on work already done. The preparation of a monograph would no longer involve a chartless roaming over a boundless sea, but our materials could be used in certainty of their completeness, and in such succession as our convenience might dictate. Monographs thus made easy could not fail to cover field after field with unprecedented completeness and facility. We should in each branch be soon furnished with that clear synoptic presentation of all its important elements and results, which would enable us to give each speciality its true value and relations on the general chart of scientific co-ordination. Our general views would keep pace with our special investigations, and our minds would attain that harmony of culture characteristic of the well-developed man. Alike versed in those grand generalities which form the groundwork

of creation and practised in the study of our chosen fields of research, we should steer clear of fruitless speculation and of the bigotry of petty knowledge. Such would be the tendencies of the work proposed. What now remains is simply to do it, and for this nothing is wanting but the man, or men. The benefit is for science among all nations. The benefactor's reward will be a truly honorable distinction, and a consciousness of usefulness such as few living men can rightly claim. When we remember how the mighty dead and the honored living have given record to their best thoughts in hope that the world would not willingly let them die, it becomes in us a deed of pious duty to retrace and render legible the inscriptions on these too neglected record tablets.

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## 8. Notes on the Wilmington Gunpowder Explosion. By Professor Denison Olmsted, of New Haven.

On the 31st of May, 1854, there occurred at Wilmington, in the State of Delaware, a disastrous explosion of gunpowder. Three wagons from Dupont's mills, which are situated from three to four miles above the town, on the river Brandywine, each laden with one hundred and fifty kegs of powder, weighing in all nearly twelve thousand pounds, were following each other at small intervals, and when in the midst of the town, the powder, by some cause not well understood, was suddenly ignited. The teams with their drivers were instantly destroyed, and desolation and ruin were spread all around, attended by the demolition of a number of buildings, and the loss of several lives.

The *ordinary* effects of such a catastrophe are well known, and I do not purpose to occupy the time of the Association in describing them ; but there were a number of *extraordinary* phenomena attending the explosion, illustrating the energy and peculiar modes of action of pneumatic forces, and possibly helping to explain certain obscure phenomena of tornadoes, which appear to me to be deserving of the attention of men of science.

Not long after the occurrence, with the hope of obtaining a more correct and precise statement of the facts than could be derived from

the newspaper accounts of the disaster, I addressed a letter of inquiry to Right Rev. Bishop Lee, whose dwelling-house was situated very near the scene of explosion, and was entirely demolished. The pressing engagements of the Bishop prevented his making the report himself, but he procured it to be done by his son, Mr. Benjamin Lee, whose full and precise statement, now before me, leaves little to be desired in respect to the facts of the case. According to this authority, wagon-loads had been in the habit of following daily the same route for fifty years, without the least accident. So long impunity had produced its natural effect, to render the drivers careless and inattentive to the regulations established by the proprietors, prescribing their speed, and the distance at which they should follow each other. Agreeably to the rules, they had left the mills at intervals of half an hour; yet, on reaching town, the hinder wagons had so increased their speed that all three, on entering the town, were near together, and at the time of the explosion were only twenty-five feet apart. It appeared, therefore, that the hindmost wagon must have travelled at the unusual rate of about six miles an hour; and as parts of the road were rough and gullied, the chance of spilling portions of the powder was greatly increased. Hence some persons endeavored to account for the explosion by supposing that powder spilled from one or more of the wagons was ignited by a spark struck by a horse's hoof. Others ascribed it to the carelessness of the drivers, two of whom were known to have been smoking at the time by the side of their wagons; and others still, to a spark from some neighboring chimney. But as the loads were severally covered closely by canvas drawn over them, I cannot think that either of these hypotheses, or any other that has come to my notice, is based on evidence that is at all conclusive or satisfactory. I will therefore omit, on the present occasion, any inquiry into the cause of the explosion, and limit myself to a few observations on its more remarkable effects.

1. The mechanical forces developed exhibited prodigious *energy*. This, indeed, is no more than every one would expect from the instantaneous explosion of twelve thousand pounds of gunpowder, since, according to Hutton (Tracts, Vol. III. p. 301), the initial force of inflamed gunpowder is nearly two thousand times the pressure of the atmosphere. The immense volume of elastic matter, suddenly evolved from twelve thousand pounds of powder, expanding with an energy so

inconceivable, would displace corresponding portions of the surrounding atmosphere, and impart to it a resistless impulse in all directions. The effects corresponded to such a cause. The drivers and horses were torn limb from limb; houses were demolished; trees uprooted or twisted off; and perfect desolation impressed on surrounding objects. But several special phènomena indicated still more clearly the prodigious energy of the forces developed. A splinter of soft pine, part of a Venetian blind, in the house of Bishop Lee, distant sixty feet from the place of explosion, was driven across the room, and struck point-wise an inch board of the same material, penetrating completely through it, with as clean a cut as a steel-pointed arrow would have made. Fragments of wheel-tire with portions of the heavy oak hubs, scraps of the harness, and a few bolts, were the only remains of the wagons. Flying fragments of the wheel-tire, in many instances, lopped off large limbs of trees, with almost the smoothness left by an edge tool. One heavy piece of tire, about two feet long, was found at the top of a high hill, a quarter of a mile off. Small articles were carried to so great a height, that minute fragments continued to fall for ten or fifteen minutes after the explosion. Glass windows were broken at the distance of more than a mile. But the most astonishing proof of the great mechanical energy developed is now to be stated. Under each wagon was found a large cavity, that beneath the middle wagon being three feet in depth, and ten by five feet in area; and these holes did not appear to be excavations, but simple indentations produced by a downward compressing force. I do not recollect any single fact in the history of gunpowder explosions which more strikingly evinces the mechanical power of the agent than this. What must be the height of that granite column, having a base of fifty square feet, which would by its weight sink a hard surface like that of a constantly travelled street to the depth of five feet? How high a column of mercury would be required to produce such an effect? The force transmitted to water-pipes at the depth of four or five feet was such as to fracture them.

2. The *modus operandi* of the forces was, in many cases, singular and curious. In one of the houses overthrown, the inmates had their clothes torn off. Fragments of the wheel-tires, two feet long and under, were, in every case, either partially or wholly *straightened out*. What was the nature of the force by which such an effect could be

produced? My correspondent remarks, that peculiar effects were produced on *metallic* substances. In every case the shoes were torn from the horses' hoofs. Hinges and bolts were wrenched from doors and shutters, even where they opposed no resistance to the motion of the body to which they belonged. Castors were in many instances detached from heavy pieces of furniture.

3. The effect produced on the *animal system*, in cases where the violence was not sufficient to destroy life, was also in many instances remarkable. At the distance of a quarter of a mile from the place of explosion, men were raised from the ground, and were sometimes borne along for several feet, without being prostrated. A man on horseback, at about half that distance, was raised from the saddle, but settled into it again without injury. Persons in the immediate vicinity experienced a sense of suffocation and difficulty of breathing, followed in some instances by soreness of the throat and a slight hæmoptysis.

4. The pneumatic forces appear to have acted by the direct impulse of the elastic medium, rushing outwards, and sometimes by the inward expansion of confined air acting against a vacuum. Near objects were more commonly affected in the former way, and more remote objects in the latter. Thus the doors and windows of a house near the place of explosion were all *driven in*, while in houses at a greater distance they all fell *outwards;* and the walls of the same house, in some instances, which were on the side next the scene of explosion, fell inwards, while the opposite walls fell outwards. A piano open at the time was very little injured, while one closed, situated at a greater distance, was nearly ruined by bursting from within. Large mirrors were thrown from the mantle to the floor without being broken. But glass windows were broken at the distance of more than a mile.

5. We trace a resemblance between some of the foregoing facts and certain phenomena observed in *tornadoes*. The splinter driven through an inch board reminds me of a fact that occurred in the New Haven tornado of 1839, where a piece of board from a bureau was carried half a mile, and was found sticking in the side of a barn, having penetrated through a thick plank. In the same storm, hinges were torn from doors, as in the case of the explosion, by some mysterious force, which did not seem to exert any great violence on the

doors themselves. This mode of action, also, seems analogous to that by which, as in the explosion, shoes were wrenched from horses' feet, and castors from pieces of furniture. Clothes torn from the persons of individuals at some distance from the scene of explosion, appear somewhat analogous to feathers stripped from domestic fowls, as was the case in the New Haven tornado, and in the Ohio storm of 1842, described by Professor Loomis; and the same has been observed in various other tornadoes. The buoyant force by which persons at some distance were sustained when driven by the force of the explosion, as the rider who was lifted from the saddle and replaced without injury, has also been noticed in storms, when individuals, as well as inanimate objects, have been transported in the air to some distance, and set down upon the ground without violence. In the New Haven tornado, a coach-wheel, which was driven against a barn with such force as to leave its impress on the wall, still fell to the ground so gently as scarcely to indent it. In storms, as well as in the explosion, houses have been burst outwards, like a breaking jar filled with air, under an exhausted receiver. In the New Brunswick storm, desks were broken open, in a manner resembling the bursting outwards of the closed piano, as mentioned in the foregoing statement.

The straightening of the wheel-tire is a fact to which I remember no parallel in the description of storms, and the compression of a hard gravelly surface fifty square feet in area to the depth of five feet, as was asserted to have occurred beneath the middle wagon, was an exhibition of an elastic force to which I have recognized few equals among terrestrial forces.

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9. Account of Experiments on the alleged Spontaneous Separation of Alcohol and Water, made at the Smithsonian Institution. Communicated by Professor Joseph Henry, Secretary of the Smithsonian Institution.

At the last meeting of the American Association, a notice was given of a new process for procuring alcohol, for which a patent had been granted. The weak spirit, left to itself in a vessel of great height, was said to separate spontaneously into a strong alcohol, which

rose to the top of the column, and into a weaker spirit which was found at the bottom.

For the following statement and remarks relative to granting the patent, I am indebted to Dr. Gale, one of the principal examiners of the Patent-Office.

"When the alleged invention was presented, much doubt was expressed as to the working of the plan, and the author was requested to answer the following questions to satisfy the office on the subject: —

"'Have you employed this device for purifying alcohol or whiskey? If so, please state what kind, what size, and what proportioned apparatus you have used on a working scale, and what results you have obtained.'

"To this the applicant replies: —

"'I have used this device as a mode of separating alcohol from whiskey for several months. The column was of wrought iron, about one hundred feet high, and twelve inches in diameter. It was elevated from the cellar through and above the building; the whiskey was forced in from the upper room of the building through an iron pipe leading over the top of the column and down the inside about fifty feet. This sized column will, I find, separate about two hundred gallons of alcohol from the water, in the space of twelve hours. The larger the diameter, the more rapid the process of separation.'

"It had been stated by the party in correspondence that he had been led to the trial of the experiment by noticing that the liquor in the upper part of a tall standing cask was thought to be stronger than that drawn out near the bottom."

This statement would seem to receive some countenance from the following remarks on the same subject, in Gmelin's Treatise on Chemistry, Vol. I. p. 112, English edition: —

"Similarly, brandy kept in casks is said to contain a greater proportion of spirit in the upper, and of water in the lower part. Here again the question may be raised, whether the cask may have been filled with successive portions of different strengths, which may have disposed themselves in layers one above another."

"As to the propriety," says Dr. Gale, "of granting or refusing a patent, on the evidence before the office, in consideration of the oath of the inventor, the want of means in the office to satisfactorily verify

or disprove the experiment, and, lastly, the subsequent statement of the inventor, that he had verified the experiment by several months' work on a practical scale, these facts were regarded as good ground for issuing the patent. If the party should be found to have made a false statement, and so committed a fraud on the Patent-Office, these acts were his own, and for which he must be held responsible."

If the result said to be obtained were true, it would follow that the affinity of bodies for each other would be modified by pressure. Though, from theoretical considerations, it might not be thought impossible that the attraction of two substances for each other might be increased by an increase of pressure, yet there is no antecedent probability that the attraction would be diminished under this influence. But as an account of this invention had been widely circulated in the newspapers, its author had received from the Patent-Office the right to vend the privilege of its use, and the public were exposed to be defrauded in the purchase of that which was worthless, it seemed desirable to settle the question as to the truth of the principle by direct experiment, irrespective of theoretical considerations, and on a scale of sufficient magnitude to leave no doubt as to the result.

With this view, in behalf of the Smithsonian Institution, I accepted the proffered co-operation of Professor Schaeffer, of the Patent-Office, and directed the putting up of the necessary apparatus in one of the towers of the Smithsonian building. The determination of the density of the liquid, and the details of the experiments, were intrusted to Professor Schaeffer, to whom I am also indebted for the following account of the process employed and the results obtained.

As the successful experiment was said to have been made with a column of liquid nearly one hundred feet high, and as the pressure of such a column was given as the cause of the separation of the water or alcohol from the mixture, the repetition of the experiment should be on a corresponding scale.

The great tower of the Institution building was already fitted for experiments requiring like conveniences. A well, or series of openings giving a height of over one hundred feet, passing through several stories, was the place selected. A series of stout iron tubes of about an inch and a half in internal diameter formed the column, the total length of which was one hundred and six feet. Four stop-cocks were provided; one at bottom, one about four feet from the top, and the other two to divide the interval equally, or nearly so.

The liquor used was common rye whiskey of 44 per cent at 60° Fahr., and of 44 on the United States Revenue Hydrometer, one of which was used in testing the liquor.

The experiment commenced on the 18th of November, 1854; a leak occurring caused the trial to be limited to the lower thirty feet, after the lapse of a few hours. On the 20th, the tube was refilled, and after testing at intervals of a few days, the loss was supplied, the whole apparatus, with each cock and the top sealed up, was left to itself until December 14th, when it was again tried at each cock. With a slightly diminished quantity, about one hundred feet in height, the whole again stood until the 18th of April, 1855, when the tests were again made.

Fortunately for the result, the original liquor had been repeatedly tested at different temperatures; the contents of every vessel used to contain it having been tried at each of the several fillings of the tube, which were made on the first days of the experiment, when a leak required its discharge for the purpose of tightening the joints. A portion of the original liquid which had been set aside was also tried at the end of the experiment, and at different temperatures.

The readings of the hydrometer were made with as much accuracy as possible under the circumstances, some of them being taken late at night, and exposed in the open tower to a violent wind. No pains were spared to test the liquid under every variety of circumstances. At first, the windows of the tower were open, but for the last two or three months they were closed. Fifty-four readings were made; nineteen of which were from the original liquid, and the remainder on that drawn from the different cocks. The result may be stated as follows.

On plotting the readings of indication and temperature, they all follow nearly in the same line, the deviations of those taken from the original fluid being quite as great as those taken from either the bottom or top, even after the lapse of months. Or, in other words, within the limits of error (the extreme being but a portion of a degree of the hydrometer), there is not the slightest indication of any difference of density between the original liquor, and that from the top or bottom of the column, after the lapse of hours, days, weeks, or months. The fluid at the bottom of the tube, it must be remembered, was for five months exposed to the pressure of a column of fluid at least one

hundred feet high. This pressure, however, is much within that at which inferior champagne bottles are burst, and if pressure alone could produce such an effect, wine of that kind should have long ere this given instances of it.

As the fact has been taken for granted, and chemists of repute have made use of it, there seems good ground for thus formally refuting an error which, at first sight, would not appear worthy of being dignified by so much notice.

## IV. PHYSICS OF THE GLOBE.

### 1. Approximate Co-tidal Lines of the Pacific Coast of the United States, from Observations in the United States Coast Survey. By Professor A. D. Bache, Superintendent. (Communicated by Authority of the Treasury Department.)

The western coast of the United States, between San Diego, California, and Columbia River, extending through 13° 35′ of latitude and 6° 43′ of longitude, is divided into three reaches (see Plate); the first from San Diego to Point Conception, the second from this point to Cape Mendocino, and the third from that cape to Cape Disappointment at the mouth of the Columbia. The first reach, about two hundred and twenty miles in extent, is curved, the general trend being about N. 56° W. The second, about four hundred and thirty miles in extent, is in general straight, with moderate indentations only, and its trend is about N. 27° W. The third, three hundred and seventy miles in extent, is also nearly straight, trending nearly N. 5° E.

The soundings on the coast generally, except in the harbors, have been for the purpose of general reconnoissance, and are not detailed enough to show the configuration of the bottom.

#### *Tidal Observations.*

Tidal stations for long series of observations have been established at San Diego, San Francisco, and Astoria (Columbia River), and, between these, temporary stations at the points and for the periods

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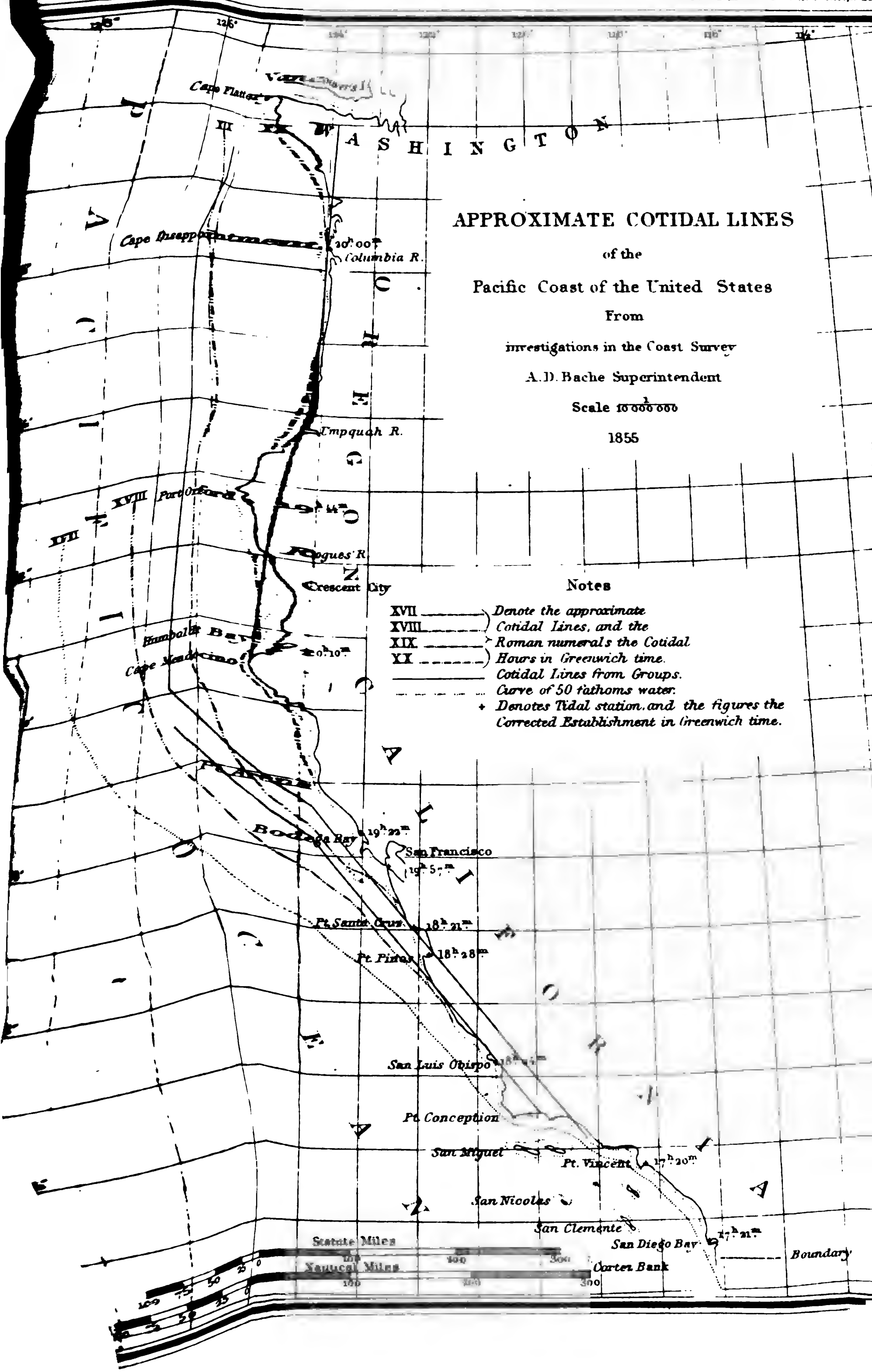

stated in the annexed general table. Saxton's self-registering gauge has been employed at the permanent stations generally, and at some of the temporary stations also.

The observations are under the direction of Lieutenant W. P. Trowbridge, U. S. Corps of Engineers and Assistant in the Coast Survey. They were commenced in 1853, and are still in progress. The very intelligent and careful supervision of this officer is a guaranty for the character of the observations. The observers, too, were especially selected by him for their faithfulness and intelligence.

The number of results collected is such as to warrant an approximate determination of the co-tidal lines of this coast, to be checked when further results are obtained. This attempt has the advantage of pointing out deficiencies in the series which otherwise would not so clearly appear. The following table shows the localities of observation and the duration of each series embraced in this discussion, the name of the observer, and the kind of gauge employed.

TABLE I.

*Tide Stations on the Western Coast of the United States, the Results of which are discussed in this Paper.*

| | Stations. | Time. | Gauges. | Observers. |
|---|---|---|---|---|
| 1 | San Diego, | 9 months (1853-4) | Self-registering, | A. Cassidy. |
| 2 | San Pedro, | 4 " (1853-4) | " | T. A. Szabo. |
| 3 | San Luis Obispo, | 2 " (1854) | Box, | G. Sherman. |
| 4 | Monterey, | 2 " (1854) | Self-registering, | J. Ord. |
| 5 | Santa Cruz, | 1 " (1853) | Staff. | |
| 6 | San Francisco, | 12 " (1853-4) | Self-registering, | G. Sherman, H. E. Uhrlardt. |
| 7 | Bodega, | 3 " (1854) | " | T. A. Szabo. |
| 8 | Humboldt Bay, | $2\frac{1}{3}$ " (1854) | Box, | J. A. Black. |
| 9 | Port Orford, | $2\frac{1}{2}$ " (1854) | Self-registering, | T. A. Szabo. |
| 10 | C. Disappointment, | 2 " (1854) | Staff, | J. A. Black. |
| 11 | •Astoria, | 9 " (1853-4) | Self-registering, | I. Wayne. |

These results were in part tabulated by Lieutenant Trowbridge, and in part in the Tidal Division of the Coast Survey Office, under the immediate direction of Assistant L. F. Pourtales. The discussions were made in general by Messrs. Heaton and Hawley, of the same Division.

The times of high water are referred to the next preceding transit of the moon, transit F of Mr. Lubbock's nomenclature, the epoch

having been found to correspond to that transit. The mean interval between the time of the moon's transit and the time of high water, or the establishment corrected for half-monthly inequality for each station, is given in the following table. A correction to carry the results to deep water is applied in the way described in my paper on the Cotidal Lines of the Atlantic Coast of the United States,* giving the establishment used in obtaining the co-tidal hour. The latitude and longitude from Greenwich of each tidal station are given in the table to the nearest minute. The co-tidal hour found from the establishment, corrected for depth and the longitude from Greenwich, is in the last column of the table. It is not necessary to apply a correction for the different transits, as the difference between the greatest and least corrections amounts to but five minutes.

TABLE II.

*Data for the Co-tidal Lines of the Pacific Coast of the United States.*

| | Stations. | Corr. Est. | Correction for Depth. | Final Corr. Est. | Latitude N. | Longitude W. | Co-tidal Hour. |
|---|---|---|---|---|---|---|---|
| | | h. m. | | h. m. | ° ′ | ° ′ | h. m. |
| 1 | San Diego, . . | 9 42 | 10 | 9 32 | 32 42 | 117 13 | 17 21 |
| 2 | San Pedro, . . | 9 37 | 10 | 9 27 | 33 43 | 118 16 | 17 20 |
| 3 | San Luis Obispo, | 10 4 | 3 | 10 1 | 35 11 | 120 43 | 18 4 |
| 4 | Monterey, . . . | 10 20 | 0 | 10 20 | 36 36 | 121 54 | 18 28 |
| 5 | Santa Cruz, . . | 10 16 | 3 | 10 13 | 36 57 | 122 0 | 18 21 |
| 6 | San Francisco, North Beach, | 11 56 | 9 | 11 47 | 37 48 | 122 26 | 19 57 |
| | Bodega, . . . | 11 19 | 9 | 11 10 | 38 18 | 123 3 | 19 22 |
| 8 | Humboldt Bay, . | 12 2 | 9 | 11 53 | 40 45 | 124 10 | 20 10 |
| 9 | Port Orford, . . | 11 26 | 0 | 11 26 | 42 44 | 124 29 | 19 44 |
| 10 | Columbia River, Cape Disappointment, | 12 0 | 16 | 11 44 | 46 17 | 123 56 | 20 0 |

### *Co-tidal Hours.*

The co-tidal hours thus far obtained between San Diego and Cape Disappointment, Columbia River, are contained between $17^{h.}\ 20^{m.}$ and $20^{h.}\ 10^{m.}$, increasing as a general rule, but with striking exceptional cases and not regularly, in passing northward. The co-tidal hour of $17^{h.}\ 20^{m.}$ characterizes the two stations in the southern reach referred to in the description of the coast. $18^{h.}$, $19^{h.}$, $20^{h.}$ are found on the middle reach, and $20^{h.}$ characterizes the northern.

* Proceedings of the Amer. Assoc. for the Adv. of Science, Washington Meeting, 1854.

*Co-tidal Groups.*

In discussing these results, I have followed the same course as in the paper on the Co-tidal Lines of the Atlantic, dividing the stations into natural groups, and applying Lloyd's mode of discussion of magnetic lines to them.

The *northern group* of stations, between Cape Disappointment and Cape Mendocino (see Plate), is composed of Cape Disappointment, Port Orford, and Humboldt. The mean co-tidal hour is $19^{h.}\ 58^{m.}$. The mean of the longitudes of the stations is 124° 12′; the mean of the latitudes, 42° 15′. Calling the differences between the mean longitude and the longitude of each station when reduced to nautical miles $x$, the differences between the latitude of each station and the mean $y$, the difference between the co-tidal hour at each station and the mean co-tidal hour $z$, and assuming $\Sigma$ as the sign of the algebraic sum of the numerical quantities obtained for the co-efficients of the equations furnished by each station, we form and solve the equations

$$M\Sigma x^2 + N\Sigma xy = \Sigma xz;$$
$$N\Sigma xy + M\Sigma y^2 = \Sigma yz.$$

In the case before us, $M$ gives for the co-efficient of the longitude 1.2, and $N$ for that of latitude —0.006. The tangent of the angle which the co-tidal line makes with the meridian $-\frac{N}{M} = 0.05$ and the angle is 2° 52′. The distance in nautical miles perpendicular to the co-tidal line corresponding to one minute of establishment, or $\sqrt{M^2 + N^2}$, is 1.2 miles, and therefore the progress of the tide-wave in one hour fifty miles.

This is a velocity less than the depth would indicate to be correct, and, from the small differences in the establishments of the stations, this must be an uncertain datum. We shall see, however, that in the next group, where the establishment varies more considerably, this datum is still less probable than the one here obtained.

The direction of the line is nearly coincident with that of the trend of the coast, the co-tidal angle being 2° 52′, and the general trend of the coast differing but two degrees from it.

The co-tidal hours calculated from the separate equations are, for Cape Disappointment, $20^{h.}\ 0^{m.}$, for Port Orford, $19^{h.}\ 44^{m.}$, agreeing pre-

cisely with the observed, and for Humboldt, $20^{h.}$ $9^{m.}$, differing but one minute from the observed.

The observations bearing upon this group are extending northward, but the difficulties in the way of maintaining the stations are such, on a coast inhabited by aborigines, that I do not venture to count upon speedy results. Lieutenant Trowbridge is using his best efforts to establish the necessary stations.

I precede the discussion of the *middle group* of stations by the table on page 149, which gives the results corresponding to several different hypotheses, which will, in turn, be examined.

Taking the five stations between Cape Mendocino and Point Conception as one group, we find from the table the angle of the co-tidal line with the meridian, N. 35° 30′ W., and the mean co-tidal hour, $18^{h.}$ $50^{m.}$; the difference of establishment for one geographical mile perpendicular to the co-tidal line, 4.7 minutes. As the observations at Santa Cruz are comparatively few in number, it may be more proper to leave out that station, which will give for the corresponding results to those just stated, N. 36° 43′ W. for the angle of the co-tidal line, $18^{h.}$ $58^{m.}$ for the mean co-tidal hour, and 3.9 minutes for the co-tidal difference in one geographical mile.

Omitting Bodega from this group, we obtain for the co-tidal angle, N. 37° 26′ W.; for the mean co-tidal hour, $18^{h.}$ $50^{m.}$; and for the change of hour in one mile, 3.9 minutes.

Omitting Bodega and San Francisco from the first group, the three southern stations, San Luis Obispo, Monterey, and Santa Cruz, give, for the same values, N. 33° 6′ W., $18^{h.}$ $18^{m.}$, and 4.9 minutes. The direction of the co-tidal line being nearly the same, its denomination only is changed. The 18¼ hours would give nearly 18¾ if carried to the co-tidal line of the first hypothesis, $18^{h.}$ $50^{m.}$, which is a good agreement.

Omissions at the other end of the group produce the same result. Leaving out San Luis Obispo from 1, we obtain for the co-tidal angle, N. 36° 30′ W.; co-tidal hour, $18^{h.}$ $47^{m.}$; change per mile, 4.4 minutes. The same result is obtained by other omissions in the series.

The introduction of Humboldt into a group with Bodega and San Francisco gives results materially different from those obtained, reducing the co-tidal angle to 18° 5′, and increasing the velocity to forty miles per hour.

TABLE III.

*Discussion of the Middle Group of Tidal Stations between Cape Mendocino and Point Conception.*

| | Stations. | Mean Longitude. | Mean Latitude. | Mean Co-tidal Hour. | $M$ Diff. of Co-tidal Hour for one Geogr. Mile of Longitude. | $N$ Diff. of Co-tidal Hour for one Geogr. Mile of Latitude. | Angle $\left[\tang = \frac{M}{N}\right]$ Co-tidal Angle. | $\sqrt{M^2 + N^2}$ Diff. of Co-tidal Hour corresponding to one Geographical Mile perpendicular to Co-tidal Line. | Miles per Hour, Tidal Wave. | Observed — Computed Co-tidal Hour for San Luis Obispo. | Monterey. | Santa Cruz. | San Francisco. | Bodega. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | h. m. | | | ° ′ | | | m. | m. | m. | m. | m. |
| 1 | San Luis Obispo, Monterey, Santa Cruz, San Francisco, Bodega, | 122 1 | 36 58 | 18 50 | 3.83 | 2.73 | 35 30 | 4.7 | 13 | 7 | 12 | —30 | 12 | 4 |
| 2 | San Luis Obispo, Monterey, San Francisco, Bodega, | 122 2 | 36 58 | 18 58 | 3.11 | 2.32 | 36 43 | 3.9 | 15 | 1 | 1 | | 2 | 8 |
| 3 | San Luis Obispo, Monterey, San Francisco, | 121 41 | 36 32 | 18 50 | 3.07 | 2.35 | 37 26 | 3.9 | 15 | | | | | |
| 4 | San Luis Obispo, Monterey, Santa Cruz, | 121 32 | 36 15 | 18 18 | 4.1 | 2.7 | 33 6 | 4.86 | 13 | | | | | |
| 5 | Monterey, Santa Cruz, San Francisco, Bodega, | 122 21 | 37 25 | 18 47 | 3.5 | 2.6 | 36 30 | 4.42 | 14 | | | | | |
| 6 | Monterey, San Francisco, Bodega, | 122 28 | 37 34 | 19 16 | 3.35 | 2.6 | 37 37 | 4.2 | 14 | | 0 | | —1 | —2 |

The combination of San Pedro with the southern stations also changes the result so rapidly, as to prove that the group is limited to the south of Point Conception.

The proof seems complete, that these five stations form a single group. Using the determination in which Santa Cruz is omitted, for reasons already stated, we have for the co-tidal angle N. 36° 43′ W., which gives an inclination to the general line of the coast of about ten degrees. The line of nineteen hours meets the coast north of Point Año Nuevo, and between it and Point San Pedro.

The comparison of the observed and computed establishments from either of these hypotheses is very satisfactory; — from that of the five stations, Santa Cruz alone stands out with a difference greater than fifteen minutes. For the second list of four stations, the greatest difference is twelve minutes, and the mean, without regard to signs, is but six minutes.

The velocity of the tide-wave is less satisfactory from the other data, rising to but fifteen miles per hour. The depth should give a greater velocity, and the comparison with the northern group would indicate a much greater.

In drawing the chart of co-tidal lines I have not followed the velocities strictly. This group, however, lies favorably for the determination of the rate of motion of the tide-wave, and the results of the various hypotheses in the table are quite consistent with each other in giving a low velocity.

The *southern group* is imperfect, as having but two stations in it. Further observations are required here, and on the islands which separate Santa Barbara Sound from the great ocean.

Combining San Luis Obispo with San Diego and San Pedro would require a retrograde wave, showing that they do not belong to the same group.

The computations required in these discussions were generally made by Mr. Heaton of the Tidal Division, under my immediate direction or that of Assistant Pourtales.

### *Chart of Co-tidal Lines.*

From this discussion I have drawn a chart of approximate co-tidal lines for the coast of Oregon and California. (See Plate.)

The chart, on a scale of $\frac{1}{10,000,000}$, the same which was used in presenting the co-tidal lines of the Atlantic coast of the United States, shows the general configuration of the coast.

The co-tidal hours are marked near the several tidal stations.

The straight lines resulting from the discussion of the northern and middle groups are delineated; for the northern group, the co-tidal lines of XIX. and XX. hours, and for the middle group, of XVII., XVIII., XIX., and XX. hours.

The curves representing the approximate co-tidal lines of XVII., XVIII., XIX., and XX. hours are drawn in dotted lines, the character of the dots differing for the several lines.

The line of XVII. hours $20^{m.}$ would follow the coast nearly from San Diego to Point Conception, then the line of XVIII. hours nearly to Point Pinos. North of this point, the lines of XVIII. and XIX. hours meet the coast obliquely at an angle of about ten degrees, the line of XX. hours appearing near Point Arena, and following the coast generally to Cape Disappointment, the receding parts having a little later, and the projecting parts a little earlier hour.

Throughout the extent of coast examined, the co-tidal lines are either sensibly parallel to, or make a small angle with, the general direction of the coast. The angle made with the coast between Point Conception and Cape Mendocino is greater than is general on the long reaches of the Atlantic coast.

The successive charts of co-tidal lines of the Pacific have been tending towards the representation now given, as more reliable observations have been collected.

The last chart, in 1848, of the Master of Trinity (Rev. W. Whewell),* to whom this subject owes so much of its progress, in comparison with that of Rear Admiral Lutke,† or with his own earlier map,‡ shows this tendency, the inclination of the lines to the coast being lessened at each step.

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* Royal Society's Transactions, Vol. LXVI., 1848.

† Bulletin de la Classe Physico-Mathematique de l'Acad. Imp. des Sciences de Petersbourg, Tom. II. No. 1.

‡ Royal Society's Transactions, Vol. LI., 1833.

2. NOTICE OF THE TIDAL OBSERVATIONS MADE ON THE COAST OF THE UNITED STATES ON THE GULF OF MEXICO, WITH TYPE CURVES AT THE SEVERAL STATIONS, AND THEIR DECOMPOSITION INTO THE CURVES OF DIURNAL AND SEMI-DIURNAL TIDES. By A. D. BACHE, Superintendent U. S. Coast Survey. (Communicated under authority of the Treasury Department.)

*Abstract.*

THE stations are eighteen in number; at four, hourly observations were made for one year or more; and at the remainder, for not less than two lunations, and generally for more. The stations at Cape Florida, Indian Key, Key West, and Tortugas, were intended to trace the tide-wave through the Florida Channel; those at Egmont Key (Tampa), Cedar Keys, and St. Mark's, to trace it along the western coast of Florida; at St. George's, Pensacola, Fort Morgan, Cat Island, and E. Bayou (entrance to the Mississippi), to trace it along the south coast of Florida, Alabama, Mississippi, and part of Louisiana; at E. Bayou, Dernière Isle, Calcasieu, Bolivar Point and Galveston, Aransas and Brazos Santiago, for the coast of Louisiana and Texas.

The observations were chiefly made by Mr. Gustavus Würdemann, with different assistants. At a few stations they were made by Corporal Thompson of the Engineers, Mr. Bassett, Mr. Tansill, and Mr. Muhr. The reductions were made in the Tidal Division of the Coast Survey Office by Assistant Pourtales, Mr. Gordon, Mr. Mitchell, Mr. Heaton, and others. The methods used were those pointed out in my previous papers to the Association, the decompositions being in some cases made graphically, and at a part of the stations, where the semi-diurnal wave is considerable, the ordinary method of working was employed, as well as those considered peculiarly applicable to these tides.

As it would be tedious to present the results of these elaborate discussions in detail, when the co-tidal lines are introduced, I have thought it best briefly to refer now to the types of the different tides, and to present to the Association the diagrams for the several stations, showing upon a uniform scale the normal curves and their decompositions into the diurnal and semi-diurnal waves.

3. Notice of Earthquake Waves on the Western Coast of the United States, on the 23d and 25th of December, 1854. (Communicated by A. D. Bache, Superintendent U. S. Coast Survey, under authority of the Treasury Department.)

In February, 1855, I received from Lieut. W. P. Trowbridge of the Corps of Engineers, Assistant in the Coast Survey, in charge of the tidal observations on the Pacific coast, a letter calling my attention to the singular curves traced by the self-registering tide-gauge at San Diego on the 23d and 25th of December, and remarking that the irregularities of the curve could not be produced by disturbances from storms, as the meteorological records for the whole coast showed a continuance at that time of an ordinary state of weather, and the length of the wave was too great to be explained by such action. "There is every reason to presume," he continues, "that the effect was caused by a submarine earthquake." No shock, however, had been felt at San Francisco.

When the record sheet of the self-registering gauge at San Francisco was received, similar irregularities in the curves for the same days were found upon it. The sheet for Astoria presented little or no special irregularity. These were the only self-registering gauges actually in operation at this time.

Waves of short period would, of course, escape detection by the ordinary hourly or half-hourly observations.

About the 20th of June, we received accounts from Japan of a violent earthquake on the 23d of December, the notice of which was more circumstantial than usual from the damage to the Russian frigate *Diana* in the port of Simoda, on the island of Niphon, from the excessive and rapid rise and fall of the water.

A detailed account of the phenomena of this earthquake, and of the rise and fall of the sea produced by it in different places on the coasts of the Pacific, is much to be desired, and I have thought that, by the publication of the results obtained by the Coast Survey, the publication of official reports of the phenomena might be induced. Perhaps even similar observations may have been made, and these registers of the self-acting tide-gauge will show what observations it is desirable to have for comparison.

Thus far we are left to the public prints for the information obtained,* and the different accounts are quite discrepant where they give details, and are usually, as intended merely for general information, too vague in the statements to give satisfactory means of comparison.

A correspondent of the New York Herald writing from Shanghae gives the following notes, stated to be derived from an officer of the frigate *Diana*: —

" At 9 A. M. on the 23d of December, weather clear, thermometer 72°, barometer $30^{in.}$, a severe shock of an earthquake was felt on board the frigate, shaking the ship most severely. This shock lasted full five minutes, and was followed at quick intervals by rapid and severe shocks for thirty minutes.

" At $9^{h.}$ $30^{m.}$ A. M. the sea was observed washing into the bay in one immense wave, thirty feet high, with awful velocity. In an instant the town of Simoda was overwhelmed, and swept from its foundations. . . . . .

" This advance and recession of the water occurred five times. . . . . .

" By $2^{h.}$ $30^{m.}$ P. M. all was quiet."

A communication in the same paper, purporting to give an extract from the log-book of the *Diana*, states that, —

" At a quarter past nine, without any previous indication, the shock of an earthquake, which lasted two or three minutes, causing the vessel to shake very much, was felt both on deck and in the cabin.

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* Since reading this paper, I have received, through the kindness of Commodore M. C. Perry, a copy of a letter from Captain H. A. Adams, U. S. N., who visited Japan in the steamer *Powhatan*, to exchange ratifications of the treaty between Japan and the United States. Captain Adams says: " Simoda has suffered dreadfully since your visit there. On the 23d of December there were several shocks of earthquake. The sea rose in a wave five fathoms above its usual height, overflowing the town, and carrying houses and temples before it in its retreat. When it fell, it left but four feet of water in the harbor. It rose and sunk this way five or six times, covering the shores of the bay with the wrecks of boats, junks, and buildings. Only sixteen houses were left standing in the whole place. The entire coast of Japan seems to have suffered by this calamity. Yedo itself was injured, and the fine city of Osaka entirely destroyed."

Captain Adams then gives an account of the disaster to the Russian friagate *Diana*, Admiral Pontiatine commanding, which was so injured in the harbor of Simoda as to lead finally to her entire loss.

At ten o'clock a large wave was observed entering the bay. . . . . . The rising and falling of the water were very great, the depth varying from less than eight to more than forty feet; and these changes, at intervals of about five minutes, continued until noon. . . . . . Scarcely had half an hour elapsed, when the rising and falling of the water became more violent than before. Between this time and a quarter past two (when the agitation again became much less) the frigate was left four times on her side, and once while thus laid, in only four feet of water. . . . . .

"Continuing to decrease in violence and frequency by 3 P. M., the agitation of the water, and the motion of the vessel consequent thereon, were very slow. . . . . . At this time a fresh west wind was blowing, the barometer stood at $29^{in.}.87$, and the thermometer was 10.5 degrees R. (about 55.6 degrees F.)"

The official report of the disaster to the frigate will probably contain further and more precise particulars of the phenomena.

Mr. P. W. Graves gives, in the Polynesian, a notice, for which I am indebted to Mr. Meriam, of an extraordinary rise and fall in the waters at Peel's Island, one of the Bonin Islands, on the 23d of December. The first rise noticed was fifteen feet above high water, followed by a fall which left the reefs entirely bare. The hour when this occurred is not stated. "The tide continued to rise and fall during the day, at intervals of fifteen minutes, gradually lessening" until the evening.

At Peel's Island the waters rose on the evening of the 25th of December to the height of twelve feet. I have not, however, seen any notice of an earthquake on that day.

I present to the Association a copy of the curves traced by the self-registering gauges at the Coast Survey tidal stations at San Diego, San Francisco, and Astoria, on the 23d and 25th of December, 1854. (See Plate.)

The curves representing tides of short period being traced upon the falling or rising curve of the regular tide, their peculiarities are not so readily seen as when shown in the second diagram (see Plate), where the regular tidal curve is represented as a horizontal line. The times of the San Diego curve are reduced to San Francisco time. The curve at San Diego presents many minor irregularities, from the motion of the float not having been sufficiently checked to prevent the recording of the waves caused by the wind.

Upon a falling tide, the crests of these waves will be met earlier, and the hollows later, than upon a horizontal surface, and the intervals from crest to crest, or from hollow to hollow, will be affected by the change of rate of fall. Upon a rising tide, the reverse will occur.

There can be no doubt that these extraordinary rises and falls of the water at short intervals, were produced by the same cause which determined the extraordinary rise and fall in the harbor of Simoda in Japan, and at Peel's Island.

The *San Francisco* curve presents three sets of waves of short interval. The first begins at about $4^{h.}$ $12^{m.}$, and ends at $8^{h.}$ $52^{m.}$, the interval being $4^{h.}$ $40^{m.}$ The second begins at about $9^{h.}$ $35^{m.}$, and ends at $13^{h.}$ $45^{m.}$, the interval being $4^{h.}$ $10^{m.}$ The beginning of the third is about $13\frac{3}{4}$ hrs., and its end is not distinctly traceable.

The crest of the first large wave of the three sets occurred at the respective times of $4^{h.}$ $42^{m.}$, $9^{h.}$ $54^{m.}$, and $14^{h.}$ $17^{m.}$, giving intervals of $5^{h.}$ $12^{m.}$ and $4^{h.}$ $23^{m.}$

The average time of oscillation of one of the first set of waves was $35^{m.}$, of one of the second $31^{m.}$, and of one of the third about the same. The average height of the first set of waves was .45 of a foot on a tide which fell two feet, of the second .19 of a foot on a tide which rose three feet, of the third somewhat less than .10 of a foot on a tide which fell some seven feet. The phenomena occurred on a day when the diurnal inequality of the tide was very considerable. The greatest fall of the tide during the occurrence of the first set of waves was .70 ft., and the corresponding rise .60 ft. In the second, the corresponding quantities were .30 ft., and in the third, .20 ft. These waves would not have attracted general attention.

There is a general analogy in the sequence of the waves of the three sets, which seems to mark them as belonging to a recurrence of the same series of phenomena. In the diagram No. 3, A (see Plate), the heights of the successive waves of the first set at San Francisco are shown by the dots joined by full lines, and of the second, by those joined by the fine dotted lines. The full lines show the heights of the first series at San Diego, and the broken lines the heights of the second. The heights in hundredths of a foot are marked at the side of the diagram, and those of the successive waves are placed at regular intervals, the waves being numbered from 0 to 7 at the top of the diagram. The height is the mean of the fall from a crest to a hollow,

and of the succeeding rise from the same hollow to the next crest. The times of oscillation from one crest to the next succeeding are placed on the same diagram, the times being written at the right hand, and the wave being designated at the lower part of the diagram No. 3, B. The full line represents the times of the first series at San Francisco, and the broken line the times of the second. The full and broken faint lines represent the times of the first and second series at San Diego. The intervals between the times of occurrence of the crests of the successive waves in the first and second series diminish from $5^{h.}$ $10^{m.}$ to $4^{h.}$ $48^{m.}$ by irregular differences.

The effect of the rising or falling tide upon which these waves occur is of course greater in disturbing the heights than the times.

The series itself looks like the result of several impulses, not of a single one, the heights rapidly increasing to the third wave, then diminishing as if the impulse had ceased, then being renewed, then ceasing, leaving the oscillation to extinguish itself.

If we had a good scientific report of the facts as they occurred at Simoda, the subject would lose the conjectural character which must otherwise belong to it. Although we have no account of the place where the earthquake had its origin, the violence of its effects in Japan, and the diminished effects at Peel's Island, show that Japan was certainly not far from the seat of action.

Five successive waves of considerable height are spoken of as having occurred at Simoda, while by the gauge we trace eight, of which seven are of considerable height. The highest wave at Simoda was estimated at thirty feet; at Peel's Island, fifteen feet; — at San Francisco it was 0.65 ft., and at San Diego in the first series, 0.50 ft.

At *San Diego* the same three series of waves are distinctly shown. The first begins $1^{h.}$ $22^{m.}$ later than at San Francisco, correction having been made for the difference of longitude, and ends $0^{h.}$ $52^{m.}$ later. The interval is $30^{m.}$ less than at San Francisco, the oscillations being rather shorter than at the last-named point. The second begins at $0^{h.}$ $54^{m.}$ later than at San Francisco, and ends $34^{m.}$ later. The third begins about $54^{m.}$ later than at San Francisco. The average time of oscillation of the first set of waves is $31^{m.}$, and of the second $29^{m.}$, being respectively $4^{m.}$ and $2^{m.}$ less than of the corresponding series at San Francisco.

The average height of the first set of waves was 0.17 ft. lower than

at San Francisco, and of the second as much higher. This fact, taken with the difference in the times of oscillation, leads me to suppose the difference in the two series due to interference, which is also suggested by the position of San Diego in reference to the islands separating the Santa Barbara Sound from the ocean.

The general analogy in the succession of heights of the mean of the two series, as shown in diagram No. 3, C, and in the times, as shown in D of the same diagram, is very satisfactory.

The difference in the periods of the tide at which the waves occurred would tend to cause discrepancies.

The first series occurred on a rising tide of 4 feet, while at San Francisco it was upon a falling one of 2 feet. The second began near high water, and was chiefly upon a falling tide of 7 feet; while at San Francisco it was upon a rising tide of 4 feet.

The forms of some of the individual waves in the second series at San Francisco and San Diego accord remarkably, as those marked 1, 3, 4, 5, and 6, when reduced to the horizontal line. The comparison on the curve where the distortion remains is also very instructive. The waves marked 1, 4, 6, and 7 are not unlike in the first and second sets at San Diego.

The observations at San Diego confirm then, in general, the inferences derived from those at San Francisco.

The register at Astoria throws no new light upon the subject. The bar at the entrance of the Columbia River would explain why the oscillations were lost or greatly reduced at Astoria, even if they arrived off the entrance of the river. The disturbance is marked on the register, but in an irregular and confused manner. It was also, apparently, preceded by unusual oscillations of the water.

After allowing for the very free action of the float of the San Diego gauge, there appear to have been indications of disturbance previous to the great earthquake shocks and following them, occurring at intervals for several days after the 23d of December. The San Francisco gauge presents similar indications.

No special effect appears to have been produced upon the time or height of high or low water by the earthquake, which merely caused series of oscillations upon the great tidal wave.

I now proceed to draw from these results some conclusions as to the progress of the ocean wave accompanying the earthquake.

The latitudes and longitudes of the places referred to are as follows:—

| | Latitude N. | | Longitude. | | W. | |
|---|---|---|---|---|---|---|
| | ° | ′ | ° | ′ | h. | m. |
| San Diego, . . | 32 | 42 | 117 | 13 | 7 | 49 |
| San Francisco, . | 37 | 48 | 122 | 26 | 8 | 10 |
| Simoda, . . . | 34 | 40 | 221 | 2 | 14 | 44 |

The distance from San Diego to Simoda from these data is 4,917 nautical miles, and from San Francisco to Simoda, 4,527 nautical miles.

According to one account, the disturbance began at Simoda at 9 A. M., or $22^{d.}\ 23^{h.}\ 44^{m.}$ Greenwich mean time, and the first great wave, half an hour after. The first disturbance at San Francisco was at $23^{d.}\ 4^{h.}\ 12^{m.}$, or $12^{h.}\ 28^{m.}$ after that at Simoda, and the first great wave at $23^{d.}\ 4^{h.}\ 42^{m.}$, giving the same interval. The distance and time from this account give for the rate of motion of the wave 363 miles per hour, or 6 miles per minute. The second account would give for the time of transmission $12^{h.}\ 13^{m.}$, and for the rate of motion 370 miles per hour, or 6.2 miles per minute.

The San Diego observations give for the time of transmission of the wave from Simoda to San Diego $13^{h.}\ 50^{m.}$ by the first account, which, combined with the distance, gives 355 miles per hour, or sensibly the same result as derived from the beginning at San Francisco. The first great wave would give identically the same result.

From the results obtained, we may determine the mean depth of the Pacific Ocean in the path of the earthquake waves. We have found for the rate of motion from 6 to 6.2 miles per minute, and for the duration of an oscillation 35 minutes at San Francisco, and 31 at San Diego. This would give for the length of the wave on the San Francisco path 210 to 217 miles; and on the San Diego path, 186 to 192 miles. A wave of 210 miles in length would move with a velocity of 6 miles per minute in a depth of 2,230 fathoms (Airy, *Tides and Waves*, Encyc. Metrop., p. 291, Table II.); one of 217 miles, with a velocity of 6.6 miles per minute in a depth of 2,500 fathoms. The corresponding depth on the San Diego path is 2,100 fathoms.

The disturbance of the 25th of December presents at San Francisco three sets of waves of seven each, and at San Diego one set of seven, agreeing in their general features with those at San Francisco, and then a set of seventeen, in which, at first, intermediate waves seem to

be wanting at San Francisco, or which have no analogous oscillations there. The crests of the first set occurred at a mean about $17^{m.}$ earlier at San Diego than at San Francisco; the heights on the average were nearly the same, being 0.39 ft. at San Diego and 0.44 ft. at San Francisco, and the time of oscillation at the two places the same, namely $41^{m.}$ The origin of the disturbance was probably nearer to San Diego than to San Francisco.

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4. Discussion of the Secular Variation in the Magnetic Declination on the Atlantic and Gulf Coast of the United States, from Observations in the 17th, 18th, and 19th Centuries. By Charles A. Schott, U. S. Coast Survey. [Abstract from a Report to the Superintendent of the Coast Survey, dated July 6th, 1855, and communicated by authority of the Treasury Department.]

This investigation was undertaken with a view of deducing the reduction to the same epoch of any of the Coast Survey observations for magnetic declination, and also with a view of predicting or calculating the declination for positions occupied prior to the present time, as well as to restore from present observations the declination at some earlier date.

The extensive use of the compass in the surveys of public lands renders a knowledge of the law of change in the direction of the needle during this and the latter half of the last century an object of great importance, the aid of which law is not unfrequently required in legal proceedings. Though an investigation of the observations taken during the last decennium would have furnished approximate results for the immediate purposes of the survey, yet it is apparent that no general law could be deduced in this way, and it became necessary at once to include all available material, from the earliest time to the present. The discussion is based upon 180 observations taken at stations distributed over the Atlantic and Gulf coast.

In reference to terrestrial magnetism in general, Professor Hansteen has lately published his investigations on the secular variation of the

magnetic inclination, in the *Astronomische Nachrichten*, Nos. 947, 948, and 954. (See for a short abstract, *Comptes Rendus*, Tom. XL. No. 15.) The appearance of this paper, and the necessity of the reduction of our observations for declination published in the Superintendent's annual report for 1854, gave a new impulse to this and similar investigations.

Beyond the fact of the nearly stationary condition of the direction of the needle about the commencement of this century in the North-eastern States, and the observed increase of westerly declination in opposition to the former decrease of the same in the New England States, little was known in reference to the law of the secular change, either in time or in geographical relation. It is to Dr. Bowditch and Professor Loomis that we are mostly indebted on this subject; to the former for having called attention to the phenomenon at the time when the change from the direct to the retrograde motion took place, to the latter for a collection of numerous observations of magnetic declinations in the United States, and also for two charts of isogonic lines for the years 1838 and 1840. Professor Loomis states that all the observations indicate a retrograde motion of the needle, which commenced as early as 1819, and in some places perhaps as early as 1793. "The present (1840) annual change of the variation is about 2 minutes for the Southern States, 4 minutes for the Middle, and 6 for the New England States." (See Silliman's Journal of Science and Art, Vol. XXXIX., 1840.)

In the following discussion I have used nearly all the data I was able to collect. There can be no doubt that much additional information might be obtained from the surveys of public lands, as their results generally are derived from a number of observations at different places, and for this reason are more likely to be free from any local deviation, the effect of which is more to be guarded against than errors of observation. Results obtained by the ordinary surveyor's compass thus show at the stations Providence, Hatboro', and others, the best agreement. In order to obtain reliable results for the secular change, it is essential that the observations should be made at the same spot; but this is seldom the case, and to this circumstance differences, amounting in some instances to half a degree and more, must be attributed.

The observations at stations mentioned in the following pages have

been discussed in three different ways, depending on the dates of their commencement and termination. Those prior to the middle of the eighteenth century require, as will be seen in the discussion, a function involving an additional term in the expression for the declination; to this class belong the stations Providence, R. I., Hatboro', Pa., and Philadelphia. Others reaching as far back as these are too discordant for use. Observations taken on shipboard are unreliable on account of local attraction, and hence have not been employed in the discussion. The second class includes observations made subsequent to the middle of the eighteenth century at the three stations before named, and at seven others, and reaching to the present time. The third class includes all stations having two or more observations of comparatively recent date; and these, as may be remarked, are less important for deducing the secular change than for the construction of the isogonic lines.

Throughout the discussion, westerly declination has been considered as positive, and easterly as negative. The formulæ used, being the same for all stations, require but once to be explained, and are given in full in the discussion of the first station of the first and second class. All observations have been scrutinized, and the references are affixed to the results. The separate heads into which the subject divides itself are as follows: —

*a.* Discussion of the secular change at stations with reliable observations dating prior to about the year 1740.

*b.* Discussion of the secular change at stations with reliable observations dating after that time.

*c.* Statement of results from comparatively recent observations.

*d.* Establishment of formulæ expressing the secular variation of the magnetic declination at any place within the limits of the discussions. Synopsis of results, and general remarks.

We commence with the discussion of the observations comprised under the head *a.*

*a. Discussion of the Secular Variation of the Magnetic Declination, from the oldest reliable Observations, viz. those recorded at Providence, R. I., Hatboro', Pa., and Philadelphia.*

The first-named set includes 30 observations made between 1717 and 1845; the second, commencing with the year 1680, presents 18

observations made at equal intervals, terminating with the year 1850; the third contains 10 observations recorded between the years 1701 and 1847.

*Method and Formulæ for the Reduction.*

The magnetic declination $D$ at the time $t$ may be expressed by the following series:

$$D = d_0 + y\,(t + t_0) + z\,(t - t_0)^2 + u\,(t - t_0)^3 + \ldots\ldots\ldots$$

where $y\;z\;u \ldots.$ are unknown co-efficients and $D$ becomes $d_0$ when $t$ equals $t_0$.

Putting $d_0 = d_1 + x$, where $x$ is a small correction to the assumed value $d$, and omitting the 4th and higher powers of the time, the above equations become

$$D = d_1 + x + y\,(t - t_0) + z\,(t - t_0)^2 + u\,(t - t_0)^3.$$

If we assume for $t_0$ the commencement of any year, and for $d_1$ the supposed corresponding declination (expressed in degrees and decimals), then each observed value for $D$ at the time $t$ furnishes an equation of the form

$$0 = d_1 - D + x + y\,(t - t_0) + z\,(t - t_0)^2 + u\,(t - t_0)^3,$$

and known as a conditional equation. By application of the method of least squares, we form the normal equations, and obtain the coefficients $x, y, z, u$.

The above formula is capable of giving two maxima and two minima, whereas the omission of the third power would give but a minimum, and this, as we know from observation, took place about the commencement of this century. The omission of the term involving the third power constitutes the difference of the classifications *a* and *b*.

The year 1830 has been assumed throughout the discussions for the arbitrary value $t_0$, for a reason which will appear in the comparison of the results at different stations.

Let $\epsilon_0$ be the probable error of a single observation,

$n$, the number of observations,

$\Delta$, the difference of observed and computed values;

then $$\epsilon_0 = 0.674\sqrt{\frac{\Sigma\,\Delta^2}{n - 4}}.$$

Differentiating the equation

$$D = d_0 + y\,(t - t_0) + z\,(t - t_0)^2 + u\,(t - t_0)^3,$$

we obtain the condition for the maximum and minimum:

$$\frac{d\,D}{d\,t} = y + 2\,z\,(t - t_0) + 3\,u\,(t - t_0)^2 = 0.$$

Changing $t$ into $\tau$ and $\tau'$ for the time of the minimum and maximum, we find,

$$\tau = t_0 - \frac{z}{3\,u} + \sqrt{\left(\frac{z}{3\,u}\right)^2 - \frac{y}{3\,u}}, \text{ and } \tau' = t_0 - \frac{z}{3\,u} - \sqrt{\left(\frac{z}{3\,u}\right)^2 - \frac{y}{3\,u}}.$$

The point of inflexion, or the time of maximum annual variation, will be found by putting the second differential co-efficient zero:

$$\frac{d^2D}{d\,t^2} = 2\,z + 6\,u\,(t - t_0) = 0.$$

Changing $t$ into $\tau''$ for the time of maximum annual variation, we have

$$\tau'' = t_0 - \frac{z}{3\,u}.$$

The maximum declination $\delta$ becomes known by substituting $\tau'$ for $t$ in the formula for $D$.

The first differential co-efficient gives the formula for the annual variation $v$,

$$v = y + 2\,z\,(t - t_0) + 3\,u\,(t - t_0)^2.$$

Substituting $\tau''$ for $t$, we find the maximum annual change $V$.

We have next to find the probable errors of the quantities $x$, $y$, $z$, $u$, $\tau$, $\tau'$, $\tau''$, &c., by forming the weight-equations, which will give the necessarily positive quantities $Q_1$, $Q_2$, $Q_3$, $Q_4$.

$\epsilon$ expresses generally a probable error, and its index indicates to which quantity this probable error refers. We have

$$\epsilon_x = \epsilon_0\,\sqrt{Q_1},$$
$$\epsilon_y = \epsilon_0\,\sqrt{Q_2},$$
$$\epsilon_z = \epsilon_0\,\sqrt{Q_3},$$
$$\epsilon_u = \epsilon_0\,\sqrt{Q_4}.$$

To find the probable error of $\tau$, $\tau'$, $\tau''$, we differentiate the expression for $\tau$, $\tau'$, $\tau''$ in regard to the variables $x$, $y$, $z$, $u$:

$$d\,\tau = -\frac{1}{6\,u\,A}\,d\,y - \left(\frac{1}{3\,u} - \frac{2\,z}{18\,u^2A}\right)d\,z + \left(\frac{z}{3\,u^2} + \frac{\frac{2\,z^2}{9\,u^3} - \frac{y}{3\,u^2}}{2\,A}\right)d\,u;$$

$$d\,\tau' = +\frac{1}{6\,u\,A}\,d\,y - \left(\frac{1}{3\,u} + \frac{2\,z}{18\,u^2A}\right)d\,z + \left(\frac{z}{3\,u^2} - \frac{\frac{2\,z^2}{9\,u^3} - \frac{y}{3\,u^2}}{2\,A}\right)d\,u;$$

$$d\tau'' = -\frac{1}{3u}\,dz + \frac{z}{3u^2}\,du;$$

in which expressions $A = \sqrt{\left(\frac{z}{3u}\right)^2 - \frac{y}{3u}}$.

For the above equations we can substitute

$$d\tau = l_1\,dy + l_2\,dz + l_3\,du;$$
$$d\tau' = l_1'\,dy + l_2'\,dz + l_3'\,du;$$
$$d\tau'' = \qquad l_2''\,dz + l_3''\,du;$$

hence,

$$\epsilon_{\tau} = \sqrt{l_1\,l_1\,\epsilon_y\,\epsilon_y + l_2\,l_2\,\epsilon_z\,\epsilon_z + l_3\,l_3\,\epsilon_u\,\epsilon_u};$$

$$\epsilon_{\tau'} = \sqrt{l_1'\,l_1'\,\epsilon_y\,\epsilon_y + l_2'\,l_2'\,\epsilon_z\,\epsilon_z + l_3'\,l_3'\,\epsilon_u\,\epsilon_u};$$

$$\epsilon_{\tau''} = \sqrt{l_2''\,l_2''\,\epsilon_z\,\epsilon_z + l_3''\,l_3''\,\epsilon_u\,\epsilon_u};$$

The differential equation

$$dv = dy + 2\,(t - t_0)\,dz + 3\,(t - t_0)^2\,du$$

gives the value for

$$\epsilon_v = \sqrt{\epsilon_y^2 + 4\,(t - t_0)^2\,\epsilon_z^2 + 9\,(t - t_0)^4\,\epsilon_u^2}.$$

Finally, we have

$$\epsilon_D = \sqrt{\epsilon_x^2 + (t - t_0)^2\,\epsilon_y^2 + (t - t_0)^4\,\epsilon_z^2 + (t - t_0)^6\,\epsilon_u^2}.$$

By means of these formulæ the observations have been discussed.

*Discussion of the Secular Change at Providence, R. I.*

This is a very important station, both in regard to the number and the agreement of the observations. In Vol. XLIV. of Silliman's Journal of Science and Art, 1843, a series of observations have been published, under the title, " The Variation of the Magnetic Needle at Providence, R. I., from A. D. 1717 to 1843, by M. B. Lockwood, C. E., from actual Observations on Record, and recorded Bearings of a Number of Objects."

Providence is in lat. 41° 49′ and long. 71° 24′ W.

These observations, when treated by the method just explained, are best represented by the formula

$$D = +7^\circ.437 + 0.08543\,(t - 1830) + 0.0015055\,(t - 1830)^2 + 0.000005100\,(t - 1830)^3.$$

The following table shows the differences between the observed and computed declinations: —

| $t$ | $D$ observed. | $D$ computed. | $\Delta$ | $\Delta^2$ |
|---|---|---|---|---|
| 1717 | + 9.60 | + 9.64 | + 0.04 | 0.0016 |
| 1720 | + 9.47 | + 9.46 | — 0.01 | 0.0001 |
| 1730 | + 8.92 | + 8.85 | — 0.07 | 0.0049 |
| 1740 | + 8.28 | + 8.22 | — 0.05 | 0.0025 |
| 1750 | + 7.67 | + 7.62 | + 0.05 | 0.0025 |
| 1760 | + 6.99 | + 7.08 | + 0.09 | 0.0081 |
| 1770 | + 6.49 | + 6.63 | + 0.14 | 0.0196 |
| 1780 | + 6.27 | + 6.29 | + 0.02 | 0.0004 |
| 1790 | + 6.18 | + 6.10 | — 0.08 | 0.0064 |
| 1800 | + 6.25 | + 6.09 | — 0.16 | 0.0256 |
| 1810 | + 6.40 | + 6.29 | — 0.11 | 0.0121 |
| 1820 | + 6.66 | + 6.73 | + 0.07 | 0.0049 |
| 1830 | + 7.19 | + 7.44 | + 0.25 | 0.0625 |
| 1840 | + 8.42 | + 8.45 | + 0.03 | 0.0009 |
| 1842 | + 8.65 | + 8 69 | + 0.04 | 0.0016 |
| 1844.8 | + 9.25 | + 9.05 | — 0.20 | 0.0400 |

Treating the observations at the other stations in a similar manner, we obtain the following results: —

*Synopsis of Results at the Stations Providence, Hatboro', and Philadelphia.*

Providence, . . . $D = +7^\circ.439 + 0.08543\,(t - 1830) + 0.001505\,(t - 1830)^2 + 0.00000510\,(t - 1830)^3$.

Hatboro', . . . . $D = +2^\circ.683 + 0.07211\,(t - 1830) + 0.001749\,(t - 1830)^2 + 0.00000675\,(t - 1830)^3$.

Philadelphia, . . . $D = +2^\circ.573 + 0.06582\,(t - 1830) + 0.001838\,(t - 1830)^2 + 0.00000742\,(t - 1830)^3$.

For $t$, any year might be substituted between 1670 or 1680 and the present time. The agreement of the co-efficients is satisfactory, at the same time exhibiting their dependence on the geographical position of the stations.

| | | $V$ |
|---|---|---|
| Providence, . | $v = +\overset{\circ}{0}.085 + 0.00301\,(t - 1830) + 0.0000153\,(t - 1830)^2$ . | $\overset{\prime}{3}.8$ |
| Hatboro', . . | $v = +0.072 + 0.00350\,(t - 1830) + 0.0000203\,(t - 1830)^2$ . | 4.8 |
| Philadelphia, | $v = +0.066 + 0.00368\,(t - 1830) + 0.0000223\,(t - 1830)^2$ . | 5.2 |

| | $\tau$ | $\tau'$ | $\tau''$ | $\delta$ | $d$ | Range. |
|---|---|---|---|---|---|---|
| Providence, . . . | 1795.6 | 1667.7 | 1731.6 | $+ 11\overset{\circ}{.}5$ | $+ 6\overset{\circ}{.}1$ | $5\overset{\circ}{.}4$ |
| Hatboro', . . . . | 1806.1 | 1681.3 | 1743.6 | + 8.5 | + 1.9 | 6.6 |
| Philadelphia, . . . | 1809.5 | 1688.3 | 1747.4 | + 9.0 | + 1.9 | 7.1 |

| | $\epsilon_0$ | $\epsilon_x$ | $\epsilon_y$ | $\epsilon_z$ | $\epsilon_u$ |
|---|---|---|---|---|---|
| Providence, . | ± 5′ | ± 0.035 | ± 0.00199 | ± 0.000057 | ± 0.00000044 |
| Hatboro', . . . | ± 11 | ± 0.077 | ± 0.00414 | ± 0.000040 | ± 0.00000070 |
| Philadelphia, . . | ± 24 | ± 0.179 | ± 0.01100 | ± 0.000250 | ± 0.00000220 |

| | $\epsilon_\tau$ | $\epsilon_{\tau'}$ | $\epsilon_{\tau''}$ | $\epsilon_V$ |
|---|---|---|---|---|
| Providence, . . . . | ± 6.1 years. | ± 9.6 years. | ± 9.3 years. | ± 1'.0 |
| Hatboro', . . . . . | ± 19.3 " | ± 5.0 " | ± 12.9 " | ± 1.0 |
| Philadelphia, . . . | ± 16.7 " | ± 26.5 " | ± 26.9 " | ± 4.0 |

According to the results deduced from the observations made at these three stations, the minimum declination took place in 1804 ± 9 years. At this time the needle had approached nearest to the true north, the western declination being greater before and after this time. The maximum variation appears to have occurred in 1679 ± 10 years. Hence the duration of half an oscillation, if we are allowed to draw the inference, would be 125 years ± 15; but this must at present be considered as speculative. The uniformity in the epoch of the minimum for a great geographical extent in a north and south direction, as we shall see farther on, would lead to the inference of a constant duration of half an oscillation in the geographical direction indicated. At Paris and London the maximum of eastern declination (equivalent to a minimum of western) took place about 1680, and the maximum of western declination about 1815, with a range of not less than 34°, while the average range at the above three stations is but 6°. The maximum of westerly declination in the northwestern part of Europe, therefore, took place nearly simultaneously with the minimum westerly declination on the eastern coast of the United States. I shall return to this subject after the discussion of the observations comprised under the head *b*. The maximum annual variation $V$ took place in 1741 ± 10 years, and if after an equal interval of time $\tau - \tau''$, or 63 years, the greatest annual change should again take place, we must expect it about the year 1867 ± 15 years. Observations made during the present year indicate an increasing change, so far supporting this conjecture. The average value of $V$ for the three stations is 4'.6, showing at the same time an increase with an approach to the line of no variation.

*b. Discussion of the Secular Variation of Magnetic Declination from reliable Observations dating subsequent to the Year* 1740, *with others made prior to that Time.*

From the preceding discussion, it is obvious that all the observations after the time $\tau''$ can be represented by an equation of the second degree, which will give the epoch of the minimum, its corresponding

and all other declinations between that time (the former point of inflection of the curve) and the present. This formula will apply up to the time of a second point of inflection, yet to be observed.

Although this class includes stations with observations reaching considerably beyond the middle of the eighteenth century, yet for want of general conformity such have been omitted in the discussion. For the purpose of a ready comparison of the *co-efficients* of the terms involving the interval of time for the several stations, and for the purpose of ascertaining their change with reference to geographical position, a rediscussion of the preceding three stations becomes necessary, in which the observations after 1740 alone are used.

The stations have been arranged in the order of their geographical position, commencing with the observations in the New England States.

| No. | Station. | Observations included between | Number of Observations. |
|---|---|---|---|
| 1 | Boston, Mass. | 1700 and 1847 | 8 |
| 2 | Cambridge, Mass. | 1708 " 1855 | 20 |
| 3 | Providence, R. I. | 1740 " 1845 | 25 |
| 4 | New Haven, Conn. | 1761 " 1849 | 13 |
| 5 | New York, N. Y. | 1609 " 1846 | 12 |
| 7 | Hatboro', Pa. | 1750 " 1850 | 11 |
| 6 | Philadelphia, Pa. | 1750 " 1846 | 8 |
| 8 | Charleston, S. C. | 1775 " 1849 | 5 |
| 9 | Mobile, Ala. | 1809 " 1850 | 5 |
| 10 | Havana, Cuba, | 1726 " 1850 | 3 |

Treating these observations by the preceding formulæ, we find the following results: —

*Synopsis of Results of the Discussion for Secular Variation at the* 10 *preceding Stations.*

| No. | Station. | Lat. | Long. | Declination. |
|---|---|---|---|---|
| | | ° ′ | ° ′ | ° |
| 1 | Boston, | 42 20 | 71 2 | $D=+8.356+0\ 0647\,(t-1830)+0.000624\,(t-1830)^2$ |
| 2 | Cambr. | 42 23 | 71 7 | $D=+8.553+0.0702\,(t-1830)+0.000720(t-1830)^2$ |
| 3 | Provid. | 41 49 | 71 24 | $D=+7.575+0.0764\,(t-1830)+0.000959\,(t-1830)^2$ |
| 4 | N. Haven, | 41 18 | 72 55 | $D=+5.395+0.0500(t-1830)+0.000857\,(t-1830)^2$ |
| 5 | N. York, | 40 43 | 74 0 | $D=+5.071+0.0642\,(t-1830)+0.000944\,(t-1830)^2$ |
| 6 | Hatboro', | 40 7 | 75 8 | $D=+2.861+0\ 0683(t-1830)+0.001169\,(t-1830)^2$ |
| 7 | Philadel. | 39 58 | 75 10 | $D=+2.599+0.0684(t-1830)+0.001340\,(t-1830)^2$ |
| 8 | Charlest. | 32 45 | 79 51 | $D=-3.330+0.0485\,(t-1830)+0.000722\,(t-1830)^2$ |
| 9 | Mobile, | 30 14 | 88 0 | $D=-7.238+0.0072\,(t-1830)+0.000123\,(t-1830)^2$ |
| 10 | Havana, | 23 9 | 82 22 | $D=-6.076+0.0098(t-1830)+0.000255\,(t-1830)^2$ |

| No. | Station. | $\epsilon_0$ | $\tau$ | $\epsilon_\tau$ | $d$ | Annual Variation. |
|---|---|---|---|---|---|---|
| | | ′ | | | ° | ° |
| 1 | Boston, | ± 13 | 1778.2 | ± 11.3 yrs. | + 6.68 | $v = + 0.065 + 0.00125 (t - 1830)$ |
| 2 | Cambr. | ± 5 | 1781.2 | ± 1.8 " | + 6.83 | $v = + 0.070 + 0.00144 (t - 1830)$ |
| 3 | Provid. | ± 8 | 1790.1 | ± 2.2 " | + 6.05 | $v = + 0.076 + 0.00192 (t - 1830)$ |
| 4 | N. Haven, | ± 12 | 1800.8 | ± 4.1 " | + 4.67 | $v = + 0.050 + 0.00171 (t - 1830)$ |
| 5 | N. York, | ± 16 | 1796.0 | ± 6.1 " | + 3.98 | $v = + 0.064 + 0.00189 (t - 1830)$ |
| 6 | Hatboro', | ± 8 | 1799.5 | ± 1.2 " | + 1.87 | $v = + 0.068 + 0.00224 (t - 1830)$ |
| 7 | Philadel. | ± 20 | 1804.5 | ± 3.1 " | + 1.69 | $v = + 0.068 + 0.00268 (t - 1830)$ |
| 8 | Charlest. | ± 10 | 1796.4 | ...... | − 4.16 | $v = + 0.048 + 0.00144 (t - 1830)$ |
| 9 | Mobile, | (± 6) | 1800.6 | ...... | − 7.35 | $v = + 0.007 + 0.00024 (t - 1830)$ |
| 10 | Havana, | (± 5) | 1810.8 | ...... | − 6.17 | $v = + 0.010 + 0.00051 (t - 1830)$ |

| No. | Station. | $v$ in 1850. | $\epsilon_v$ | $\epsilon_x$ | $\epsilon_y$ | $\epsilon_z$ |
|---|---|---|---|---|---|---|
| | | ′ | ′ | ′ | | |
| 1 | Boston, | + 5.4 | ± 0.5 | ± 8 | ± 0.0061 | ± 0.00016 |
| 2 | Cambridge, | + 5.9 | ± 0.1 | ± 2 | ± 0.0017 | ± 0.00002 |
| 3 | Providence, | + 6.9 | ± 0.2 | ± 3 | ± 0.0028 | ± 0.00004 |
| 4 | New Haven, | + 5.0 | ± 0.4 | ± 4 | ± 0.0047 | ± 0.00009 |
| 5 | New York, | + 6.2 | ± 0.6 | ± 7 | ± 0.0080 | ± 0.00012 |
| 6 | Hatboro', | + 6.8 | ± 0.1 | ± 3 | ± 0.0008 | ± 0.00005 |
| 7 | Philadelphia, | + 6.8 | ± 0.5 | ± 8 | ± 0.0082 | ± 0.00011 |
| 8 | Charleston, | + 4.6 | ..... | .... | ....... | ........ |
| 9 | Mobile, | + 0.7 | ..... | .... | ....... | ........ |
| 10 | Havana, | + 1.2 | ..... | .... | ....... | ........ |

The order in which the stations have been arranged serves to show the dependence of the co-efficients $x$ $y$ $z$ upon the geographical position of the stations; but the last two co-efficients will be investigated further on, as on these alone depends the secular change and the time of the minimum.

The epoch of the minimum ($\tau$) appears to be subject to local irregularities, as disclosed by the probable errors ($\epsilon_\tau$), and a general law or dependence on the same cause is strongly marked as affecting every station on the Atlantic seaboard, and is even traceable from the southern shore of Hudson's Bay to Jamaica. The mean $\tau$, without regard to the probable error, is 1796, and when we form the differences, $\tau$ — mean, the figures at once show that in the Eastern States the minimum of magnetic declination took place about a decennium earlier, and about the same number of years later, in the Eastern Gulf States, than in the Middle States. In the last section this geographical relation of the co-efficients $y$ and $z$, and of the epoch $\tau$, will be more fully investigated. It is no more suprising to find local deviations in the epoch of the minimum, than in the declination itself.

The general flatness of the curves, as we approach the Gulf of Mexico, is remarkable, and induced me to collect a few observations for declination at Jamaica, W. I., lat 17° 58′, long. 76° 46′. Permanent declination at Kingston, Jamaica, from 1660 to 1800, 6° 30′ E. (J. Robertson, Phil. Trans. Royal Society, 1806). Declination from a plan of Kingston, by J. Leard, in 1791 and 1792, 6° 45′ E., and by the same authority in 1789 and 1793, 6° 50′ E. On Minories' map, published in London, 1854, the declination is given 4° 40′ E., which is probably for 1833. Colonel Sabine, in the Phil. Trans. Royal Society, Part II. 1849, Contrib. IX., gives the declination —3°.8 and —4°.2, the mean of which is 4° E. (for 1840?) The latter two determinations show that there is an end to the permanency in the direction of the needle since the commencement of this century. Sir John Herschel says: "The whole mass of West Indian property has been saved from the bottomless pit of endless litigation by the invariability of the magnetic declination in Jamaica and the surrounding Archipelago during the whole of the last century; all surveys of property there have been conducted solely by the compass." Examining, on the other hand, the declinations at Fort Albany, at the southern extremity of Hudson's Bay, lat. 52° 22′, long. 82° 38′, we find declination in 1668, according to Halley, 19° 15′ W. (see Hansteen's *Erdmagnetismus*, Vol. I.); declination in August, 1730, according to Captain Middleton, 23° 0′ W.; and by the same authority, declination in Sept. 1774, 17° 0′ W. Hansteen's map for 1787 gives 14° W., and Barlow's map for 1833 (Phil. Trans.) 3° W. We may here particularly notice the maximum, which must have taken place between 1668 and 1730. Hence we see that the curves for these extreme stations agree well in their general character with the previous investigation, which is thereby considerably expanded in the direction of the meridian, and it becomes a matter of interest to examine the same in the direction of the parallel, which, however, does not come within the compass of this paper.

*c. Statement of Results from comparative recent Observations and Discussion of some Anomalous Stations.*

The discussion at Burlington, Vt., lat. 44° 28′, long. 73° 14′, has shown that the curvature appears to be greater than usual, and that the minimum is displaced to 1808 ± 4. The observations are represented by

$$D = +8^{\circ}.363 + 0.1207\,(t - 1830) + 0.002755\,(t - 1830)^2.$$

At Chesterfield, N. H., lat. 42° 53′, long. 72° 20′, the same late minimum, 1814.1, has been deduced by the formula,

$$D = +7^{\circ}.040 + 0.1053\,(t - 1830) + 0.003289\,(t - 1830)^2.$$

At Salem, Mass., lat. 42° 31′, long. 70° 54′, the curvature is again very considerable, as seen by the co-efficient of the expression,

$$D = +7^{\circ}.420 + 0.1235\,(t - 1830) + 0.002137\,(t - 1830)^2.$$

The disturbed region around Cape Ann, extending as far as Salem, is also manifested in the secular variation.

At Nantucket, Mass., lat. 41° 17′, long. 70° 6′, the observations are represented by

$$D = +8^{\circ}.232 + 0.0612\,(t - 1830) + 0.000534\,(t - 1830)^2,$$

but the minimum falls very early; the formula gives

$$\tau = 1772.8.$$

For Albany, N. Y., lat. 42° 39′, long. 73° 44′, we find

$$D = +6^{\circ}.356 + 0.0682\,(t - 1830) + 0.00128\,(t - 1830)^2,$$

and

$$\tau = 1803.4.$$

At Washington, D. C., and Pensacola, Fa., the observations are as yet too few in number to be submitted to a discussion, but this may be done as soon as a new determination can be had. The same may be said of Milledgeville, Ga., Savannah, Ga., and New Orleans, La.

New observations at the stations Burlington, Nantucket, Albany, and perhaps Chesterfield, will render them available for the general discussion. The early minimum at Nantucket is probably as anomalous as the late minimum at Chesterfield. The preceding discussion, with the exception of the result at Nantucket, tends again to a later minimum for stations to the northward of New York and Boston. The best value, at present deducible, for the epoch of the minimum, including the whole geographical extent, may be assumed to be the general mean of $\tau$, which is 1797.2 ± 8.0 years.*

* From observations down to September, 1855, the average $\tau$ becomes 1797.6 ± 1.8 years.

*d. Establishment of Formulæ expressing the Secular Variation in the Magnetic Declination at any Place within the Geographical Limits of Stations named in the Discussions.*

We have seen that the co-efficients in the formula for the magnetic declination depend upon the geographical position of the station, and it now remains to express this dependence analytically.

The declination has been expressed by the formula

$$D = C + C' (t - 1830) + C'' (t - 1830)^2,$$

where $C$ is a constant (the former $x$) and $C' + C''$ stands for the former co-efficients $y$ and $z$.

Now $C'$ may be expressed by a formula involving a constant term and terms of differences of latitude and longitude, namely,

$$C' = c' + x + y (l - L) + z (m - M) \cos l + u (l - L)^2 + v (m - M)^2 \cos^2 l,$$

where $c'$ is an average value of all the $C'$, $L$ the mean latitude, $M$ the mean longitude, and $x$, $y$, $z$, $u$, $v$, co-efficients to be determined.

The following table has been formed from the preceding discussion:

| Station. | $l$ | $m$ | 10000 $C'$ | 1000000 $C''$ |
|---|---|---|---|---|
| | ° | ° | | |
| Boston, | 42.3 | 71.0 | 647 | 624 |
| Cambridge, | 42.4 | 71.1 | 702 | 720 |
| Providence, | 41.8 | 71.4 | 764 | 959 |
| New Haven, | 41.3 | 72.9 | 500 | 857 |
| New York, | 40.7 | 74.0 | 642 | 944 |
| Hatboro', | 40.1 | 75.1 | 683 | 1169 |
| Philadelphia, | 40.0 | 75.2 | 684 | 1340 |
| Charleston, | 32.8 | 79.8 | 485 | 722 |
| Mobile, | 30.2 | 88.0 | 72 | 123 |
| Havana, | 23.1 | 82.4 | 98 | 255 |
| Mean, | $L = 37.5$ | $M = 76.1$ | $c' = 528$ | $c'' = 771$ |

Putting $l - L = \lambda$, $(m - M) \cos l = \mu$, and $c' - C' = \Delta'$, we obtain the conditional equation

$$0 = \Delta' + x + y\lambda + z\mu + u\lambda^2 + v\mu^2.$$

Substituting the above values, and forming the conditional and normal equations, we find the values for $x$, $y$, $z$, $u$, and $v$, as follows:

$x = +79$; $y = +24$; $z = +2.5$; $u = -0.28$; and $v = -3.42$.

Hence the expression for $C'$ becomes

$$C' = +0.0607 + 0.00240\lambda + 0.00025\mu - 0.000028\lambda^2 - 0.000342\mu^2.$$

The original equations are represented as follows:—

| Station. | $C'$ | $C'$ comp'd. | $\Delta$ |
|---|---|---|---|
| Boston, | 0.0647 | 0.0658 | + 0.0011 |
| Cambridge, | 0.0702 | 0.0663 | — 0.0039 |
| Providence, | 0.0764 | 0.0655 | — 0.0109 |
| New Haven, | 0.0500 | 0.0668 | + 0.0168 |
| New York, | 0.0642 | 0.0669 | + 0.0027 |
| Hatboro', | 0.0683 | 0.0665 | — 0.0018 |
| Philadelphia, | 0.0684 | 0.0668 | — 0.0016 |
| Charleston, | 0.0485 | 0.0463 | — 0.0022 |
| Mobile, | 0.0072 | 0.0080 | + 0.0008 |
| Havana, | 0.0098 | 0.0114 | + 0.0016 |

This is a satisfactory agreement, as appears from a comparison of the average probable error $\epsilon_y$ (of a former table), and the probable error of $C'$, as deduced from the above $\Delta$.

We have $\epsilon_y = \pm\ 0.0046$, and $\epsilon_{c'} = 0.674\sqrt{\dfrac{\Delta^2}{n-5}}$;
$\epsilon_{c'} = \pm\ 0.0063$;

hence the above formula represents the co-efficient $C'$ nearly as close as it was itself deduced at the separate stations.

Similarly the second co-efficient $C''$ may be expressed by

$$C''=c''+x+y(l-L)+z(m-M)\cos l+u(l-L)^2+v(m-M)^2\cos^2 l$$

and

$$0=\Delta''+x+y\lambda+z\mu+u\lambda^2+v\mu^2.$$

We find

$$C''=+0.000850+0.000196\,\lambda+0.000251\,\mu+0.000008\,\lambda^2-0.000023\,\mu^2.$$

This formula does not represent the values of $C''$ as closely as we might have expected, yet differences of 0.000200 might have been anticipated from an inspection of $C''$ for Hatboro' and Philadelphia. The greatest difference is for Providence, namely, —0.000274. When the station for which $C''$ is to be found is situated within the range of the position of the above places, the formula may be applied; yet it will be found preferable to make use of a more simple relation of the co-efficients $C'$ and $C''$. Referring to the table showing $C'$ and $C''$, their increasing ratio is apparent, and putting $C''=n\,C'$, we have for

| | | | |
|---|---|---|---|
| Boston, . . . . . . $n$ = | 0.010 | Hatboro', . . . . . $n$ = | 0.017 |
| Cambridge, . . . " | 0.010 | Philadelphia, . . " | 0.018 |
| Providence, . . . " | 0.013 | Charleston, . . . . " | 0.015 |
| New Haven, . . " | 0.017 | Mobile, . . . . . . " | 0.017 |
| New York, . . . " | 0.015 | Havana, . . . . . . " | 0.026 |

which relation is sufficiently regular to allow the interpolation of any value derived within its range.

$C'$ and $C''$ being thus known, an observed value of the declination at a given place will determine the constant $C$, and will enable us to deduce the declination for any time $t$. For this place the epoch of the minimum becomes known by the expression $1830 - \frac{C'}{2\,C''}$, and the annual variation by $v = C' + 2\,C''\,(t - 1830)$. For want of observations, the values deduced for $C'$ and $C''$ must at present be considered as approximations.*

Before concluding this paper, it was thought proper to refer to a few circumstances closely related to the preceding discussion, and tending to modify former conclusions.

1. In the Phil. Trans. Royal Society, Vol. XI. (abrid.) from 1755 to 1763, we find the paper on the variations which Professor Hansteen has made use of in the construction of some of his charts of isogonic lines in his *Erdmagnetismus*. The following is an abstract of a small part of this paper, "On the Variation of the Magnetic Needle, with a set of tables exhibiting the result of upwards of 50,000 observations, in six periodic reviews, from the year 1700 to the year 1756, and adapted to every fifth degree of latitude and longitude. By W. Mountaine and J. Dodson, F. F. R. S."

| Lat. | Long. | Declination in | | | |
|---|---|---|---|---|---|
| | | 1700. | 1730. | 1744. | 1756. |
| $25^{\circ}$ | $80^{\circ}$ | $4\frac{3}{4}^{\circ}$ E. | | $3\frac{1}{2}^{\circ}$ E. | $3^{\circ}$ E. |
| 30 | 80 | $2\frac{1}{2}$ E. | | $\frac{3}{4}$ E. | 0 |
| 35 | 75 | $2\frac{1}{4}$ W. | | $6\frac{1}{2}$ W. | 7 W. |
| 40 | 70 | 7 W. | $9^{\circ}$ W. | $11\frac{1}{2}$ W. | $12\frac{1}{4}$ W. |

Now we know from the preceding discussion, that the western declination (see the two last lines in the above table) had been *decreasing* since 1700, reached a maximum annual decrease in 1744, and continued decreasing down to about 1797, while the above table gives an *increase* during this interval of time, and is therefore entirely at variance with the observations taken on land. From this cause some

* From observations down to September, 1855, the following expression of $C'$ is deduced: $C' = +\,0.0556 - 0.00104\,\lambda - 0.00444\,\mu - 0.000165\,\lambda^2 - 0.000008\,\mu^2$.

of the geographical representations in the *Erdmagnetismus* based thereon require considerable corrections.

2. The rate of secular change used for the lines of equal magnetic declination in the Atlantic by Colonel Sabine, Phil. Trans. Royal Society, 1849, was derived from comparison with the map of declinations for 1787 in Professor Hansteen's work referred to above. This assumes a uniform progressive rate of the secular change, which, though applicable for other places, St. Helena for instance (see Colonel Sabine's paper, read May 18th, 1854), is, as we have seen, entirely inadmissible on our Atlantic coast, and may even give no rate at all for the time of the maximum rate. In consequence of this, the rates deduced in Table No. X. Trans. of 1849 are very much in error, and affect more or less the resulting isogonic lines depending on it. For lat. 40° long. 75° the table gives an annual variation for 1840 $= 0'.0$, when it should be $+5'.7$.

3. In Professor Hansteen's paper on the changes in the magnetic inclination in the north temperate zone, *Astronomische Nachrichten*, Nos. 947, 948, and 954, the declination is stated to have a retrograde motion, as inferred from Professor Loomis's table in Silliman's Journal, Vol. XXXIX., and consequently an easterly motion is assigned to the pole B (pages 187 and 192, No. 948). Again, on page 282, No. 954, it is said that in North America the *western* declination *decreases*, and the easterly increases; which, however, is not the case, as has been seen; for since the minimum, about the beginning of the present century, the reverse has taken place, the westerly declination having ever since *increased* (or the easterly diminished). Professor Hansteen's pole B, therefore, appears to have reached its most easterly position about 1797, and has ever since been moving to the *westward*.

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## 5. The Frozen Wells of Owego. By Professor John Brocklesby, of Trinity College, Hartford, Conn.

About sixteen years ago a letter was addressed to Professor Silliman, by Mr. D. O. Macomber, of Owego, Tioga Co., N. Y., describing certain unexplained phenomena pertaining to a well situated in the vicinity of Owego.

The communication of this gentleman (which is recorded in Vol. XXXVI. of the Journal of Science) is as follows: —

"The well is excavated on a table-land elevated about thirty feet above the bed of the Susquehanna River, and distant from it three fourths of a mile. The depth of the well, from the surface to the bottom, is said to be 77 feet; but for four or five months of the year the surface of the water is frozen so solid as to be entirely useless to the inhabitants. On the 23d of the present month (February), in company with a friend, I measured the depth, and found it to be 61 feet from the surface of the earth to the ice which covers the water in the well, and this ice we found it impossible to break with a heavy weight attached to a rope. The sides of the well are nearly covered with masses of ice, which, increasing in the descent, leave a space but one foot in diameter at the bottom.

"A thermometer let down to the bottom sunk 38° in 15 minutes, being 68° in the sun and 30° at the bottom of the well. The well has been dug 21 years, and I am informed by a very credible person, who assisted in the excavation, that a man could not endure to work in it more than two hours at a time, even with extra clothing, although in the month of June, and the weather excessively hot. The ice remains until very late in the season, and is often drawn up in the months of June and July. Samuel Mathews drew from the well a large piece of ice on the 25th of July, 1837, and it is common to find it there on the 4th of July.

"The well is situated in the highway, about one mile northwest of the village of Owego. There is no other well on that table of land, nor within 60 or 80 rods, and none that presents the same phenomenon. In the excavation no rock or slate was thrown up, and the water is never affected by freshets, and is what is usually denominated 'hard' or limestone water. A lighted candle being let down, the flame became agitated and thrown in one direction at the depth of 30 feet, but was quite still and was soon extinguished at the bottom. Feathers, down, or any light substance, when thrown in, sink with a rapid and accelerated motion. The above facts may be relied upon as entirely correct."

Such is the statement of Mr. Macomber. During last year I received from the Rev. Wm. H. Corning, who is settled at Owego, two letters in respect to this phenomenon, which show that it is not con-

fined to one locality. In his first communication, dated June, 1854, Mr. Corning thus writes: "Two wells in Owego, some 60 feet deep, *freeze*, and within a week large lumps of ice have been drawn up from one of them. They are situated a short distance from the Susquehanna River, and are below its bed."

In my reply to this letter Macomber's well was mentioned, and certain observations and experiments suggested, which it was thought might tend towards the solution of the problem.

In the second letter of Mr. Corning, he writes as follows: —

"The deep well spoken of by Macomber is situated at some distance *west* of the village proper, about a *quarter of a mile* from Owego Creek, and is on rather high ground; but no hills or mountains of any height are in its vicinity. The water of this well in the month of September is said to be quite *warm*; so much so as to be unpalatable.

"The *other well* (from which the ice was drawn) is in the centre of the village, not more than *seventy yards* from the Susquehanna, and is about a *quarter of a mile* from any hill. The distance from the surface of the ground to the surface of the water in the well is, at this date (Aug. 19th), 22½ feet. The water is about 18 inches deep, and its temperature was, at noon of this day, 47° Fahr.

"By letting down a lighted candle, a slightly perceptible current of air is detected, and the flame blows nearly *west* (the river is *south*). For the space of 10 or 12 feet down from the mouth of the well, there is not the least current; but for the rest of the distance, to within a foot of the water, the current mentioned is about the same in force; yet hardly strong enough to settle the question as to lateral fissures.

"The sides of the well are coated with ice from early winter, and the water apparently freezes from the bottom and sides. Sometimes the surface is frozen so hard, that it becomes necessary to drop a heavy weight to break the ice, in order that water may be drawn; this, however, is only occasionally done. The former owner was obliged to remove a chain-pump, and resort to the old windlass, on account of the ice. The ice remains on the sides of the well until the middle of May, when it gradually melts away, and by about the middle of June it is almost entirely gone. The water of the well up to the middle of May is very cold, resembling ice-water.

"The formation of this region is what geologists call *alluvial*, I *believe*. For the depth of ten feet or more below the surface of the

earth there are large quantities of pebble-stones, varying in size from that of a pea to those which measure 4 or 5 inches in diameter. These are mixed with gravel and a sandy loam, and farther down are veins or layers of gravel, free, for the most part, from these stones. The hill or mountain, from which the *village* well is about a quarter of a mile distant, is variously estimated by the inhabitants to be from 150 to 200 feet in height. Upon it are found shells and marl."

During the early part of this summer I received information similar to the above from the Rev. James Rankine, a gentleman who resides at Owego. Mr. Rankine remarks, in addition, that "when the ice begins to form in the cold weather, it can be seen forming under the surface of the water in shape like a basin; and that during last winter a cover was put upon the well, when all its usual phenomena disappeared."

I am not aware that any satisfactory explanation has yet been given of this singular phenomenon. Without claiming to solve it, the learned editor of the Journal of Science remarks, in respect to the well of Macomber, that "possibly the escape of compressed gas deep within the earth in the vicinity of the well, and in proximity to its waters, may account for the extraordinary low temperature that there prevails"; and this view he considers as perhaps countenanced by the slight current of air that exists in the well.

It is worthy of notice, that in *both* the wells the phenomena of the currents is the same; namely, that the flame of a candle is swayed in *one direction* before it reaches the bottom, where it is *still*, — facts that point towards a common cause.

A well somewhat similar to the Owego wells is found at Monte Video, a villa situated about 9½ miles from the city of Hartford, Ct.

This well is sunk through the loose trap rock and gravel to the depth of about 25 feet, and during the summer months the water that is drawn from it is as cool as iced water. So low is the temperature, that the teeth fairly ache with cold as the water is drank. In close proximity to this well is a lofty hill of trap, whose shelving sides are entirely composed of the *débris* of this rock.

In the celebrated cave of Orenburg, in Russia, we have another instance of a locality possessing in summer an extraordinary low temperature. This cavern, which is at the base of a hill of gypsum, and opens on the street of Orenburg, is partly filled with ice in the summer, the roof, which is broken by fissures, being hung with solid un-

dripping icicles; and the hotter the weather, the more severe is the cold; while in the winter all the ice disappears.

In explanation of these phenomena, it is asserted that in summer, as in the case of mining shafts and galleries, a warm current of air *descends* through the channels and passages of the hill, evaporating the water that it meets with, and cooling so rapidly, that it is below the freezing point when it issues into the cave. In the winter the current would move in the opposite direction, the hill being *warmer* than the external atmosphere.

This explanation will not serve for the wells of Owego, though it possibly may for that at Monte Video; for the *former*, unlike the cave of Orenburg, are *coated with ice and frozen in winter*, and in *midsummer* their waters are as *warm* as those of other wells. Nevertheless, it appears from the statement of Mr. Rankine, that *evaporation* aids in some way in producing the extraordinary degree of cold that prevails in these wells; for when one of them was covered, and the evaporation checked, no ice was formed within it.*

The preceding facts have been presented, not for the purpose of now offering any solution of the problem they involve, but with the hope that their publicity may stimulate observation and inquiry, and elicit other facts which will lead us to a better understanding of this class of physical phenomena.

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## V. METEOROLOGY.

### 1. On the Storm which was experienced throughout the United States about the 20th of December, 1836. By Elias Loomis, Professor of Mathematics and Natural Philosophy in New York University.

Several years ago I undertook to investigate the phenomena of a violent storm which swept over the United States about the 20th of December, 1836; and the result of my investigations was published in

* The same phenomenon, according to report, was true of the Macomber well, which has now fallen in.

the seventh volume of the Transactions of the American Philosophical Society. This storm extended from the Gulf of Mexico to an unknown distance on the north. The fluctuation of the barometer increased with the latitude, at least as far as Quebec, the most northern point from which observations could be obtained. The area embraced in the observations included, therefore, only the southern half of the storm, and the phenomena of the northern half could only be supplied by conjecture. I therefore regarded the results of this investigation as unsatisfactory; but finding it impossible to obtain observations from more northern stations, I published the information which I had obtained; and sought for some more hopeful subject of investigation in the case of a storm which should be wholly embraced within the area of our observations. Such was the storm of February 4, 1842, with regard to which I was fortunate in obtaining abundant materials for investigation. In conducting this investigation, I adopted some peculiar methods, which, so far as I have been informed, had never been practised before. The phenomena of the storm, at intervals of twelve hours, were delineated on a series of maps of the United States, in such a manner that every important feature was made to appeal directly to the eye. First, those portions of the map corresponding to places where the sky was unclouded were colored blue; those portions where the sky was overcast, but without rain or snow, were colored brown; those portions of the country where rain was falling were colored yellow; and those portions where snow was falling were indicated by a green color. The direction of the wind was represented by arrows, and its force indicated by their length.

The observations of the barometer and thermometer were represented in the following manner. Having determined, as well as I was able, the mean height of the barometer at each station, I compared each observation with the mean. I then drew on the map a line passing through all those places where the barometer, at a given hour, stood at its mean height. This line was called the line of mean pressure. I then drew a line through all those places where the barometer, at the same hour, stood two tenths of an inch *above* the mean; another line through all those places where the barometer stood four tenths of an inch above the mean, &c. Similar lines were drawn through all those places where the barometer stood two tenths of an inch *below* the mean; four tenths of an inch below, &c.

In like manner, a line was drawn joining all those places where the thermometer stood at its mean height for the given hour and month; and this was called the line of mean temperature. Another line was drawn through all those places where the thermometer stood ten degrees *above* the mean; and other lines were drawn through the places where the thermometer was twenty degrees above the mean, ten degrees *below* the mean, twenty degrees below the mean, &c.

This mode of representing the observations of the barometer and thermometer appears to me the most suitable of any which has yet been proposed to indicate the connection between the pressure and temperature of the air on the one hand, and the direction of the wind and the fall of rain on the other.

The results of the investigation of the storm of Feb. 4, 1842, were entirely satisfactory to myself, and were published in Volume IX. of the Transactions of the American Philosophical Society. Being convinced of the superior advantages of this new method of investigating the phenomena of storms, I immediately constructed a series of maps upon the same principle, representing the progress of the storm of December, 1836; and I perceived that certain features of this storm were thus brought out more clearly than I had been able before to exhibit them; but, inasmuch as the publication of a series of colored maps involves a serious expense, these maps have never been offered for publication.

As, however, my paper upon this storm has been commented upon by Messrs. Redfield and Espy, and by Dr. Hare, and some conclusions have been drawn from it which appear to me unwarranted, I have thought it expedient to bring the subject before the notice of this Association.

The five accompanying maps represent the phenomena of this storm from the evening of December 19th to the evening of December 21st, at intervals of twelve hours, the mode of representation being similar to that already mentioned as having been employed for the storm of February, 1842.

The blue color represents the region where the sky was unclouded; the brown color represents the region where the sky was overcast, but without rain or snow; the fall of snow is indicated by the green color, and rain by the yellow. The line of mean pressure is drawn upon each map, as well as the line of two tenths of an inch below the

mean. On the last three maps is also drawn the line of four tenths of an inch below the mean. In order to avoid confusion, the thermometrical lines have been omitted from these maps. As, on account of the dark color of the maps, the arrows indicating the direction of the wind could not be well seen at a distance, they have been omitted, and a separate chart has been prepared, showing the direction of the wind for the evening of December 20th.

I do not propose at present to undertake an analysis of the general phenomena of this storm; but shall confine my remarks to two points respecting which some diversity of opinion has been expressed.

The first question relates to the direction and velocity of the storm's progress. If our observations embraced the entire area of the storm for a series of days, it would be an easy matter to assign its direction and velocity, provided we can agree as to what shall be regarded as the centre of the storm. The progress of a rain-storm is generally characterized by a depression of the barometer; and perhaps there is no point to which we can more appropriately apply the term *centre of the storm*, than to that point where the depression of the barometer is greatest. Unfortunately, in the storm of December, 1836, few, if any, observations have been obtained from points north of the centre of the storm. The depression of the barometer at Quebec was greater than at any station south of it. But at Fort Snelling, near lat. 45°, on the Mississippi River, the depression of the barometer was no greater than it was at Natchez. It seems reasonable then to infer, that along the Mississippi River the point of greatest depression must have been near St. Louis; while near the Atlantic coast the centre could not have been south of Quebec. Assuming St. Louis and Quebec to lie in the central path, the direction of the storm's progress was from S. 62° W. to N. 62° E. It seems quite clear that the storm travelled towards some point north of east, and not towards the south of east, as has been inferred by Dr. Hare and by Mr. Espy. From the morning of December 20th to the morning of December 21st, the centre of the storm advanced 1,140 miles in the direction already assigned; being an average velocity of 48 miles per hour.

The second question which I propose to consider is, Was this storm a whirlwind? In order to answer this question, I have drawn, upon a separate sheet, arrows representing the direction of the wind for the evening of December 20th, being the period when the storm was most

nearly central as regards the stations of observation. At this instant we find the winds in the rear of the storm to blow from the north or northwest. Their average direction is about N. 30° W.; and this mean direction is sensibly the same in lat. 45° as near the Gulf of Mexico.

In front of the storm, the winds generally blow from points between south and southeast. Its average direction is about S. 10° E.; and in the southern part of the United States the winds are quite as much easterly as in the northern part of the United States, and perhaps even more so. We thus find that along a meridian, for a distance of at least 1,200 miles, we have on the west side a violent current setting from N. 30° W.; and on the east side, in close proximity, an equally violent current setting from S. 10° E. The most striking feature exhibited by these winds is that of two currents blowing with great violence, for at least 48 hours, in directions almost diametrically opposed to each other. This is not a whirlwind, as that term is generally understood; nor according to the diagrams of Messrs. Redfield, Reid, and Piddington. It may be admitted, indeed, that the winds show some tendency to circulate in a direction contrary to the motion of the hands of a watch; but this tendency is not the predominant feature, and the centrifugal force thus resulting can produce only insignificant effects. But how can two winds blow thus violently towards each other for 48 successive hours? This southeast wind was confined to that portion of the atmosphere which is near the earth's surface. The northwest wind being colder, and therefore heavier, than the southeast wind, flowed under it, raised it from the earth's surface, and turned it back upon itself, so that at an elevation of two or three miles above the earth's surface a westerly wind was prevailing even in front of the storm. The air thus elevated from the earth's surface was chilled by the cold of elevation; its vapor was condensed, and was precipitated in the form of rain or snow.

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2. On the Storm of October 7, 1854, near the Coast of Japan, and the Conformity of its Progression with other Cyclones. By W. C. Redfield, of New York.

Since the return of the U. S. expedition from Japan I have obtained, through the kindness of Commodore Perry and his officers, some

notices of gales encountered by the squadron while in the Pacific Ocean and the Asiatic seas.

One of these storms was encountered by the U. S. ships *Mississippi* and *Southampton*, on the 7th of October last, near lat. 35°, soon after leaving Japan on their way to the Sandwich Islands. On the 7th and 8th it was encountered by an American whaleship near lat. 45°; as appears by an extract from her log-book, for which I am indebted to Lieutenant Wm. L. Maury of the *Mississippi*. An important portion of its route, previous to and at the time of its recurvation, has also been brought to our knowledge by means of a report from Captain Briard, master of the English brig *Giffard*, then on her way from San Francisco to Shanghai, which is found in the London Nautical Magazine for February, 1855. Copies of these several reports are herewith submitted.

We have thus the necessary data for an approximate delineation of the route of this storm, which I have traced on the manuscript chart which is herewith presented. The track as thus shown may enable us to judge of its conformity with the general law of progression manifested by other cyclones, in different regions.

It will be seen that the change from a westerly to an easterly progression, in this cyclone, took place in 27° 30′ of north latitude, and eastward of the Loo Choo Islands. It is obvious that the geographical relations of its route to the equatorial zone and the northern hemisphere are not unlike those which have been shown in the storms of the North Atlantic Ocean.

In order to exhibit this accordance more perfectly, it has occurred to me to transfer a tracing of this storm-track to a chart of the North Atlantic, and one hundred and fifty degrees of longitude more eastward than its actual position, so as to interpolate it among the known tracks of the Atlantic storms. The track as thus shifted is marked in red ink on some copies of the chart which was prepared to illustrate my memoir on the Cape Verde and Hatteras hurricane and other storms, which was presented to the last meeting of the Association, at Washington.

Such comparisons of the great curves of atmospheric progression which are developed in these storm-tracks, will serve to show their remarkably persistent analogies; which clearly indicate that the same dynamical elements of rotation and progression are common to all

these storms. This view appears confirmed by nearly all the storm-routes which hitherto have been established in different regions, and must claim the careful attention of meteorologists, as well as of all who take interest in the general physics of our globe.

It may be noticed, that I have also placed on the manuscript chart the trace of the *Raleigh's* typhoon of August, 1835, which passed over Macao and Canton. It is taken from my notice of that storm which was published in Silliman's Journal for January, 1835 (Vol. XXXV., first series). I have likewise added a tracing of the course of the Manilla typhoon of October, 1831, which was noticed in the same communication, and which is supposed to have extended its course to Balasore, on the Bay of Bengal. On the eastern portion of the chart will also befound p artial tracings of the storm-routes of the Pacific, near the coast of Mexico, which were noticed in my paper presented last year to the Association, at Washington; together with four storm-routes of the United States, Gulf of Mexico, and the Atlantic, taken from the storm-chart which accompanies that paper.

The field of the new chart extends from near Newfoundland and Barbadoes on the east, across the American continent and Pacific Ocean, to near the borders of British India on the west. Indeed, with the exception of the interior of the Asiatic continent, the field of successful inquiry may now be said to encircle the globe; and includes also the principal seas of the southern hemisphere.

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# B. CHEMISTRY AND NATURAL HISTORY.

## I. CHEMISTRY.

### 1. Description of a New Apparatus for separating Gold and other Precious Metals from Foreign Substances. By E. N. Kent, of New York.

I invite your attention for a few moments to a brief description of a new apparatus for separating gold from foreign substances, which has been recently put into operation at the U. S. Assay Office in New York.

The principles involved in the construction of this apparatus are based on the following facts. Grains of gold, silver, or other ductile metals, when ground or crushed with quartz or other hard substances, flatten under the mill, and thus prevent the crushing surfaces from coming close enough to grind the stony matrix to a very fine powder. But if, when thus crushed as fine as possible, the grains of gold or other metal thus liberated are separated, the remaining stony matter can *then* be crushed to an impalpable powder, so that the finest particles of gold, and even such as are invisible to the naked eye, may be liberated, and with *proper* apparatus be saved.

To accomplish this great desideratum effectually, the mill *A* (reference to drawings,* fig. 1), and amalgamator *E*, are so constructed as to hold a large quantity of water, in each of which the earthy matters are kept constantly agitated and suspended, while the light and heavy substances are separated from each other by virtue of their respective gravities, the heavy metallic portions falling to the bottom of the columns of water, while the light and refuse earth is washed away in the current of water which constantly passes through the apparatus in the direction of the arrows (Fig. 2).

The earthy matters which have been previously crushed are supplied to the apparatus through the hopper *C*, in which the grains of gold or other precious metal (if any be present) will be retained, and cleaned by the action of the teeth on the under side of the plate *D* from the sand which would otherwise remain.

After the metallic grains have been thus separated, the earthy portion is carried by the current of water, through the tube (*r*), into and under the surface of the large body of water in the mill *A*, the light and finer portions passing off with the current of water into the amalgamator *E*, and the heavy and coarser portion falling to the bottom of the mill, where it is ground and mixed up with the water, until the earthy portion of this also passes off into the amalgamator, leaving a small residue very rich in gold at the bottom of the mill.

The earthy matters, from which the greater portion of the gold or silver has been now extracted by mechanical means, pass into the pan *H*, and are stirred up and suspended in the water by the teeth attached to the arms *I*, and are carried thence by the current of water,

* Not published.

through the small tubes ($l$ $l$), into the second large body of water, contained in the vessel $E$. Here it is brought directly in contact with the mercury on the bottom, the surface of which is kept constantly clean by the revolving action of the paddle-wheels around the shaft ($k$), which also causes an outer current in the space between the wheels and the sides of the vessel, into which the earthy matters are thrown by the revolution of the paddle-wheels upon their own axis. The heavy metallic portion is thus allowed to fall by virtue of its gravity, and remain in contact with the clean mercury until amalgamated, while the light and refuse earth is rapidly washed away.

At the close of the operations for a day, the supply of water is stopped, and the cock ($d$) opened for a few minutes, while the shaft ($b$) is still in motion, so as to draw off the small rich residue which remains at the bottom of the mill into the pail $P$, while the water passes off through the overflow-pipe into the trough ($q$), and is conducted into the traps $K$.

The rich residue thus obtained from the mill contains, besides the precious metals, sand, sulphur, and generally iron. The two latter may be oxidized and removed by roasting or burning the residue, and by passing the ashes through the grain separator $C$ at the next operation, either alone or with a fresh supply of earthy matter, the gold contained therein will be separated and cleaned. Or the residue may be fluxed with soda-ash and nitre, to remove the sand and iron, and the gold will be obtained at the bottom of the crucible.

The gold contained in the grain separator is removed through a tap at the bottom into a small pail, which for this purpose is to be hung on the hook ($n$). This is the largest and most valuable portion of the gold, and if properly cleaned by running the mill about two hours after the supply of earth has ceased, it is found to be clean and bright, and when dried is ready to be fused and cast into ingots.

The mercury in the amalgamator requires to be removed only once a week, or once a month, according to the quantity of material which has been passed through the apparatus. When sufficiently charged with gold or silver, the amalgam is to be drawn off through the cock ($i$) into the pail $P$, which retains it, and allows the water to pass off into the trap boxes $K$. The amalgam is then strained and distilled in the usual manner, and the fluid mercury returned to the amalgamator.

## II. MINERALOGY.

1. On Some New Localities of Minerals. By Sanderson Smith, of New York.

At a copper mine about a mile from the celebrated barytes mine in Cheshire, Ct., I lately obtained some specimens of native silver, in cavities in massive copper glance. One of the filaments was about three quarters of an inch long, and the tenth of an inch in diameter. Associated with these, in cavities lined with minute quartz crystals, were a number of little plates about three tenths of an inch long by one fifteenth broad, and very thin. These were flexible, and generally curved, and were tinged of a beautiful green by copper. They may possibly be crystals of tremolite. A quantity of these fill the cavities, in which they are loose, not being attached together, or to the walls of the cavity. They are consequently difficult to collect and preserve, as they generally fall out in breaking the specimens open. This mine will probably soon be worked, when we may hope for interesting specimens.

In the city of New York, about 50th Street, crystallized muscovite, with internal hexagonal markings of a lighter color, occurs. When these markings are examined by polarized light, they present a different color from the groundwork, indicating a different angle between the axes of polarization.

At Reading, Pa., allanite occurs as the gangue of zircon.

The specimens labelled malachite, from Jones's Mines, Berks Co., Pa., are generally silicate of copper, instead of carbonate. The cerusite stated to occur there must, I think, be a mistake, as no lead minerals occur there. At Steel's Mines, in the same county, very good brown garnet is found.

At Cornwall, Lebanon Co., Pa., very handsome chrysocolla is found, as well as pretty strong loadstone, and a handsomely marked jasper.

At the zinc mines near Friedensville, Lehigh Co., Pa., have lately been found some specimens of crystallized carbonate of zinc (Smithsonite), in double-pointed pyramids, of about the size and shape of caraway-seeds, scattered over the surface of a thin film of velvety iron ore, investing massive carbonate of zinc. Some also occur directly on the massive carbonate, but those on the iron ore are larger, and

make much more beautiful specimens, from the relief given by the dark ground. The crystals are much rounded, however, so that scarcely any faces can be made out. The crystallized lanthanite from this locality, described by Blake in the sixteenth volume of Silliman's Journal, is still unique. Openings are now being made at the spot where it was supposed to have been found, and we may hope that more will soon be discovered. At the allanite locality, near Bethlehem, small but very brilliant zircons occur, generally imbedded in the allanite. In some larger crystals, which are not so brilliant, the pyramidal faces are almost black, whilst the lateral faces are of a light buff color. Associated with the allanite and zircons are very acute rhombic prisms, sometimes more than an inch long, and three quarters of an inch in the longest diagonal, which are in a high state of internal alteration, though still preserving a tolerably bright surface and sharp edges. A blowpipe examination shows the presence of titanium, and the mineral will probably prove to be sphene, though no specimen exhibiting terminal planes has yet occurred. The basal cleavage is very perfect, but has the appearance of being the result of alteration, like that of the hydrated iolite.

About two miles north of Easton, Northampton Co., Pa., near the nephrite locality, some very handsome specimens of crystallized serpentine, having bright faces, and being very translucent, have been procured by Dr. Edward Swift, of Easton.

When at Chamouni last year I obtained a specimen marked "Mica Verte du Mont Rose," which has all the characters of Mr. Blake's clinochlore, and possesses a most beautiful green color, almost surpassing, I think, that from the original locality.

2. RE-EXAMINATION OF AMERICAN MINERALS. PART V. THE MINERALS OF THE WHEATLEY MINE IN PENNSYLVANIA. — ANGLESITE; CERUSITE; WULFENITE; VANADATE OF LEAD; PYROMORPHITE; MIMETENE; GALENA; COPPER; COPPER PYRITES; MALACHITE; AZURITE; BLENDE; CALAMINE; HEMATITE; FLUOR SPAR; CALC SPAR; SULPHUR, &c. By PROFESSOR J. LAWRENCE SMITH, of Louisville.*

BEFORE describing the minerals of this mine, it is well to say a word with reference to its location, and also to quote some remarks on the geology of the surrounding country by Professor H. D. Rogers. Although this is departing from the plan usually adopted, still the occurrence of all the minerals here described at one locality cannot but render the geology of the place interesting to mineralogists.

This mine is situated in Chester County, near Phœnixville, Pennsylvania, and is one of several interesting developments of a thorough and very able exploration of this region by Mr. Charles M. Wheatley. At the request of Mr. Wheatley, Professor Rogers made a geological examination of the metalliferous veins of this district, and the following remarks are taken from his report.

"These veins belong to a group of lead and copper-bearing lodes of a very interesting character, which form a metalliferous zone, that ranges in a general east and west direction across the Schuylkill River, near the lower stretches of the Perkiomen and Pickering Creeks in Montgomery and Chester Counties, and bids fair to constitute at no distant day a quite productive mineral region.

"The individual veins of this rather numerous group are remarkable for their general mutual parallelism, their average course being about N. 31° — 35° E. by compass, and not at all coincident with that of the belt of country which embraces them. They are true lodes or mineral injections, filling so many dislocations or fissures, transverse to the general direction of the strata which they intersect. The metalliferous belt ranges not far from the boundary which divides the gneissic or metamorphic rocks of Chester County from the middle secondary red shale and sandstone strata.

* The Association is indebted to Professor J. D. Dana for the figures and mathematical descriptions of the crystals given beyond.

" This vein varies in thickness from a few inches to about two and a half feet, and we may state its average width at not less than eighteen inches. It is bounded by regular and well-defined, nearly parallel walls, the prevailing material of which is a coarse, soft granite, composed chiefly of white feldspar and quartz.

" It would seem to be a pretty general fact, that such of these veins as are confined entirely or chiefly to the gneiss, bear *lead* as their principal metal; whereas those which are included solely within the red shale are characterized by containing the ores of copper. But the zinc ores, namely, zinc blende and calamine, prevail in greater or less portions in both sets of veins, existing, perhaps, in a rather larger relative amount in the copper-bearing lodes of the red shale.

" The *gneissic strata* of the tract embracing this group of lead-bearing veins seem to differ in no essential features from the rest of the formation ranging eastward and westward through this belt of country. Here, as elsewhere, they consist chiefly of soft thinly bedded micaceous gneiss, a more dense and ferruginous hornblendic gneiss, and, thirdly, a thicker-bedded granitic gneiss, composed not unfrequently of little else than the two minerals, quartz and feldspar.

" Penetrating this quite diversified formation are innumerable injections of various kinds of granite, greenstone trap, and other genuine igneous rocks. The granites, as throughout this region generally, consist for the most part of a coarse binary mixture of quartz and opaque white feldspar, tending easily to decomposition. This rock abounds in the form of dykes and veins, sometimes cutting the strata of gneiss nearly vertically, but often partially conforming with its planes of bedding for a limited space, and then branching through, or expiring in it in transverse or tortuous branches. A not uncommon variety of granitic dyke is a simple syenite composed of quartz, greenish semi-translucent feldspar, and a smaller proportion of dark green hornblende. A soft, white, and partially decomposed granite is a very frequent associate of the stronger lead-bearing veins, particularly in their more productive portions; but this material belongs, in all probability, not to the ancient granitic injections of the gneiss, but to those much later metalliferous intrusions which filled long parallel rents in that formation with the lead ores and their associated minerals.

" The gneissic strata and their granitic injections throughout this dis-

trict display a softened, partially decomposed condition, extending in many places to a depth of twenty fathoms.

"Of the dozen or more lead and copper lodes of greater or less size brought to light in this quite limited region of five or six miles' length and two or three miles' breadth, the greater number are remarkably similar in their course, ranging N. 32° — 35° E., and S. 32° — 35° W.; and what is equally worthy of note, they dip, with scarcely an exception, towards the same quarter, or southeastwardly, though in some instances so steeply as to approach the perpendicular.

"There is no marked difference in the general character of the vein-stones of the several mineral lodes, nor any features to distinguish as a class those of the red shale from those of the gneiss."

The minerals found in these veins are quite numerous, and among them there are specimens of species hardly equalled by those coming from any other locality. Professor Silliman, in his report on the minerals of this mine exhibited at the Crystal Palace, says, that the specimens of sulphate and molybdate of lead are the most magnificent metallic salts ever obtained in lead-mining, and unequalled by anything to be seen in the cabinets of Europe.

### 48. *Anglesite.*

This mineral is found abundantly and in beautiful crystals at this locality. The magnificence of many of the specimens can only be realized by seeing those in Mr. Wheatley's cabinet. The crystals are remarkable for their size and transparency; in some instances they weigh nearly half a pound, being as transparent as rock-crystal in nearly every part. Crystals with terminations at both ends have been obtained five and a half inches in length by one and a half in thickness; perfectly limpid crystals an inch in length are quite common.

The following are some of the forms: —

1. — $0,\ \infty,\ 1\text{-}\breve{\infty}$.

2. — $0,\ \tfrac{1}{2}\text{-}\bar{\infty},\ \infty\text{-}\infty,\ 1,\ \infty,\ 1\text{-}\breve{2},\ 1\text{-}\breve{\infty},\ \infty\text{-}\breve{\infty}$.

3. — $0,\ \tfrac{1}{4}\text{-}\bar{\infty},\ \tfrac{1}{2}\text{-}\bar{\infty},\ \infty,\ 1\text{-}\breve{2},\ 2\text{-}\breve{4}$.

4. — $0,\ \tfrac{1}{2}\text{-}\bar{\infty},\ \infty\text{-}\bar{\infty},\ \tfrac{3}{4}\text{-}\bar{\tfrac{3}{2}},\ 1,\ \infty,\ 1\text{-}\breve{2},\ 2\text{-}\breve{4},\ 1\text{-}\breve{\infty}$.

Sometimes the crystals of this mineral are full of cavities, and of a milk-white color; but these do not differ in composition from the colorless and transparent forms. It also occurs in circular crystals.

It is sometimes colored. There is a black variety produced by the more or less perfect admixture of the sulphurets of lead and copper (containing traces of silver) in the mass of the crystals, whose form is not altered. There are crystals of a delicate green color, arising from carbonate of copper, and others of a yellow color, due to oxide of iron.

The transparent and colorless variety is remarkably pure. Its sp. grav. is 6.35. On analysis it afforded

| | 1. | 2. |
|---|---|---|
| Sulphuric acid, | 26.78 | 26.61 |
| Oxide of lead, | 73.31 | 73.22 |
| Silica, | .20 | |
| | 100.29 | 99.83 |

according very precisely with the formula $\dot{P}b.\ \dddot{S}$.

I would call attention to the method of analyzing this sulphate, as described in another paper, for it was analyzed in the moist way by dissolving it first in citrate of ammonia.

The anglesite of this mine is found variously associated. It is common to find it in geodic cavities in galena, the cavities being lined with hematite varying in thickness from $\frac{1}{20}$ to $\frac{1}{2}$ an inch or more, and often this hematite contains anglesite intimately mixed in the mass. It may occur in crystals occupying a portion of the geode, or it may fill its entire capacity, assuming the form of the cavity. It is also found compacted in the galena, without the appearance of any cavity, or the presence of any other mineral; acicular crystals occur diffused through the galena. Observed also on copper pyrites, with a thin layer of hematite intervening between the crystal and the pyrites,— on crystals of zincblende in quartz,— on quartz associated with pyromorphite,— on galena with crystals of sulphur,— on calc spar without any associate. One very interesting specimen consists of a flattened crystal an inch square, having a delicate crystal of calc spar, over an inch and a half in length, perforating the centre, and around which the sulphate appears to have formed. It is also found on fluor spar without associate.

Some of the most beautiful specimens are where large crystals of anglesite are covered with crystals of carbonate of lead, these latter frequently penetrating the anglesite.

## 49. *Cerusite.*

The crystals of this mineral, though not as large as those of anglesite, are yet exceedingly beautiful, both in size as well as transparency: the twin crystals are often two inches broad, transparent, and presenting the appearance of the spread wing of a butterfly; some of the single crystals are an inch in length, and half an inch thick.

A transparent crystal weighing five grammes gave a sp. grav. of 6.60, and on analysis furnished

| | | |
|---|---|---|
| Carbonic acid, . . . . . | 16.38 | $\left.\begin{matrix} \\ \\ \end{matrix}\right\} = \dot{P}b\ \ddot{C}.$ |
| Oxide of lead, . . . . . | 83.76 | |
| | 100.14 | |

It occurs in hematite coating galena, in a manner similar to the anglesite, and associated with it; also in connection with pyromorphite, which often colors the entire body of the crystals of cerusite. It is found on galena without the association of any other mineral, — on green and blue carbonate of copper, — on pyromorphite, which often covers the entire surface of the cerusite crystals, imparting to them an opaque yellowish-green color, — on oxide of manganese, in snow-white crystals, without any other associate, — on hematite in a similar manner; mammillary masses of the hematite sometimes pass through the crystals. Some few specimens have been found consisting of crystals of galena, with a number of very fine hemitrope crystals of cerusite on the surface. The cerusite is occasionally covered with an exceedingly thin coat of oxide of iron, giving the crystals a dark red appearance; and some of them, again, with a very thin layer of pyromorphite, as delicate as if it had been put on with a brush.

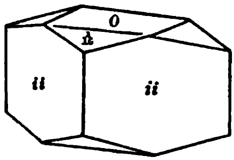
The cerusite is sometimes colored black, green, and yellow, in a manner similar to that mentioned under anglesite.

## 50. *Wulfenite.*

This mineral is found in small crystals of every shade of color, from a light yellow to a bright red; it has been found in some abundance, forming, from the manner of its occurrence, very beautiful speci-

mens. The crystals present a variety of modified forms, tabular and octahedral, one of which is here figured.

1.




Other forms are 0, 1.

0, $\frac{1}{3}$, 1.

0, $\frac{1}{16}$, $\infty$-$\infty$. (Fig. 1.)

Specific gravity of a dark yellow variety, 6.95.

The composition of both the yellow and red varieties was examined; the difference of color is due to the presence of *vanadic acid* in the red varieties, and the intensity of color is proportional to the amount of vanadic acid, which in no instance is much more than one per cent.

The analyses afforded

| | Yellow variety. | Red variety. |
|---|---|---|
| Molybdic acid, . . . . . | 38.68 | 37.47 |
| Vanadic acid, . . . . . | —— | 1.28 |
| Oxide of lead, . . . . . | 60.48 | 60.30 |
| | 99.16 | 99.05 |

The second corresponds very nearly to 97 per cent of molybdate, and 3 per cent of vanadate of lead. As the last substance varies in quantity, it cannot be regarded as giving a distinct specific character to the mineral. This mineral has been described as a chromo-molybdate of lead, but by the most careful examination only a trace of chromium can be detected; in fact, the quantity is so minute as to require further examination in larger quantities to place the matter beyond a doubt.

Wulfenite occurs alone on crystallized and cellular quartz, or associated with pyromorphite, whose beautiful green color is often very much enhanced by the contrast of the yellow and red crystals on its surface.

Sometimes the wulfenite forms the mass, and crystals of pyromorphite are sparsely disseminated over the surface. It is also found in decomposed granite, — on carbonate of lead and oxide of manganese, — also associated with vanadate of lead.

### 51. *Vanadate of Lead* (*Descloizite?*).

This species has never before been remarked among American minerals, although the chloro-vanadate (vanadinite) was first discovered in Mexico. This adds another to the list of curious minerals

from the Wheatley mine. It was noticed about a year ago in the form of a dark-colored crystalline crust, covering the surface of some specimens of quartz and ferruginous clay, associated with other minerals. Observed with a magnifying-glass, it is seen to consist principally of minute lenticular crystals, grouped together in small botryoidal masses; the crystalline structure is perfect. Thus seen, the color of the mass is of a dark purple, almost black. When seen by transmitted light, the color is dark hyacinth-red, and translucent. The streak is dark yellow. From the difficulty of obtaining any quantity of sufficient purity, nothing accurate can be stated with reference to its specific gravity and hardness; and for the purpose of analysis I was obliged to use material which, although containing pure crystals of the vanadate, was yet mixed with crystals of molybdate of lead, and other impurities.

The chemical analysis is an imperfect one, yet the best that can be made from the mineral as it has been found. It is as follows: —

| | |
|---|---|
| Vanadic acid, | 11.70 |
| Molybdic acid, | 20.14 |
| Oxide of lead, | 55.01 |
| Oxides of iron and manganese, Alumina, | 5.90 |
| Oxide of copper, | 1.13 |
| Sand, | 2.21 |
| Water, | 2.94 |
| | 99.03 |

If we subtract the amount of oxide of lead requisite to form wulfenite with the molybdic acid present, we have left 22.82 per cent, which is combined with 11.7 of vanadic acid, making a compound corresponding to, Vanadic acid 66.1, oxide of lead 33.9 = 100.

This result is not considered precise; it corresponds, however, more nearly with the composition of descloizite, as given by Damour, ($\dot{P}b^2\,\ddot{V} = \ddot{V}$ 29.3, $\dot{P}b$ . . . 70.7,) than with dechenite, by Bergmann ($\dot{P}b\,\ddot{V} = \ddot{V}$ 45.34 $\dot{P}b$ 54.66).

The composition of Descloizite cannot be considered as having been fairly made out, for Damour's results are deduced, as mine have been, from a very impure material, and may on future examination prove to be $\dot{P}b^3\,\ddot{V}^2$; corresponding in composition to the chromate of

lead called melanochroite. This mineral has as yet been found only in small quantity at this mine, associated with oxide of manganese and wulfenite, the crystals of this latter substance being more or less covered with minute crystals of the vanadate.

### 52. *Pyromorphite.*

There are several shades of color belonging to this mineral, — a green so dark as to be almost black, olive-green, pea-green, leek-green, greenish-yellow, and all intermediate shades. It is a very abundant ore at the Wheatley mine, and large quantities of it are smelted. Specimens of great beauty are found occurring in botryoidal masses with columnar structure, in perfect hexagonal prisms with the summits more or less modified. Crystals are found half an inch in diameter. Some of the crystals are hollow, with only an hexagonal shell; sometimes the crystals are agglomerated in a plumose form.

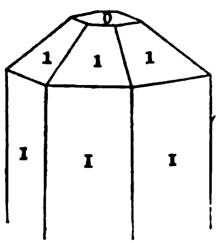
A dark green variety gave a specific gravity of 6.94. No analysis was made of this mineral, as it will be embraced in an examination of the American pyromorphites, to be published at some future time.

It is found in decomposed granite, on quartz crystals, occasionally covering their entire surface; in cellular quartz, with molybdate of lead; in large masses of grouped crystals, with small crystals of yellow and red molybdate inserted on crystals of sulphate and carbonate of lead, and forming a coating to large surfaces of galena.

### 53. *Mimetene.*

The specimens of this mineral that have been found, although few in number, are remarkable for their beauty of crystallization. Some of the crystals are nearly colorless, and perfectly transparent; others of a lemon-yellow, either pure or tinged with green. The form is that of a perfect hexagonal prism, the edges of the summit most commonly truncated, often to such an extent as to terminate the crystal with an hexagonal pyramid (Fig. 2). The crystals are sometimes as small as a hair, and a quarter of an inch, or more, in length; and again they are so broad and short, as to form hexagonal plates half an inch across.

2.



A specimen of the lemon-yellow variety was examined; it gave a specific gravity of 7.32, and was found to contain

| | |
|---|---|
| Arsenic acid, . . . . . . . | 23.17 |
| Chlorine, . . . . . . . . . | 2.39 |
| Oxide of lead, . . . . . . . | 67.05 |
| Lead, . . . . . . . . . | 6.99 |
| Phosphoric acid, . . . . . . . | .14 |
| | 99.74 |

corresponding to, Arsenate of lead 90.66, chloride of lead 9.34 = $\dot{P}b^3 \ddot{\dot{A}}s + \frac{1}{3}$ Pb Cl.

This specimen of mimetene is seen to be almost free from phosphoric acid, containing only about $\frac{1}{10}$ of one per cent, in this respect resembling that from Zacatecas, as analyzed by Bergmann.

This mineral is found in granite or quartz. It is also associated with pyromorphite, and sometimes the two run together, so as to present no distinct line of demarcation between them; some of the specimens consist of the two minerals, the pyromorphite forming one entire surface, and mimetene the opposite surface, and between, various shades of the mixture. It has been found with galena and carbonate of lead.

### 54. *Galena.*

The compact, fibrous, and crystallized varieties of galena occur at this mine. Fine crystals are found, either a perfect cube or a cube with modified edges and angles, octahedron and rhombic dodecahedron, often very much flattened out, and occasionally rounded to an almost globular form; these rounded crystals are usually covered with pyromorphite. The galena is sometimes cellular, arising from partial decomposition, the exterior portion presenting a black drusy appearance, the interior of a bright steel color; this variety is particularly rich in silver, and also contains crystals of sulphur.

The galena is argentiferous, giving an average yield of thirty ounces to the ton. It is found associated with quartz, calcite, and fluor spar, frequently inserted in the crystals of these substances; it is also a common associate of all the minerals of this locality. Some of the cubical crystals have their surfaces partly decomposed, and covered with a layer of crystals of carbonate. Specimens are found of very large cubical and octahedral crystals, forming slabs several

square feet in surface, completely covered with a layer of leek-green phosphate. The cavities of the galena frequently contain sulphur.

### 55. *Copper.*

Native copper is found only in delicate films on hematite or quartz crystal, and forms an interposing layer between the hematite and copper pyrites.

### 56. *Copper Pyrites.*

Copper pyrites is found in some cases in sufficient quantity to be worked as an ore; some of the masses are of considerable size, weighing three or four hundred pounds. Fine crystals are obtained, both tetrahedral and octahedral. It affords on analysis,

| | |
|---|---|
| Sulphur, . . . . . . . . . | 36.10 |
| Copper, . . . . . . . . . | 32.85 |
| Iron, . . . . . . . . . . | 29.93 |
| Lead, . . . . . . . . . | .35 |
| | 99.23 |

It occurs alone, and associated with the other sulphurets. It is found in various parts of the vein, there being no special point of deposit.

### 57. *Malachite.*

Malachite occurs in small reniform masses, consisting of fibrous crystals, and of a bright green color; also in silky tufts of a very light green color, which are associated with azurite and carbonate of lead. Its specific gravity is 4.06. An analysis gave,

| | |
|---|---|
| Carbonic acid, . . . . . . . | 19.09 |
| Oxide of copper, . . . . . . | 71.46 |
| Water, . . . . . . . . . | 9.02 |
| Oxide of iron, . . . . . . . . | .12 |
| | 99.69 |

affording the formula $\dot{Cu}\,\ddot{C} + \dot{Cu}\,\dot{H}$.

It is associated with the various ores of copper and lead of the Wheatley mine, and sometimes so thoroughly diffused through the sulphate and carbonate of lead, as to give them a uniform green tint. It is not found in any quantity.

### 58. *Azurite.*

This mineral, although rare, is found in beautiful crystals, some measuring from ¼ to ½ inch across, of a deep blue color, and highly polished faces. Its specific gravity is 3.88. An analysis gave,

| | |
|---|---|
| Carbonic acid, | 24.98 |
| Oxide of copper, | 69.41 |
| Water, | 5.84 |
| | 100.23 |

giving the formula $2\,\dot{Cu}\,\ddot{C} + \dot{Cu}\,\dot{H}$.

This species occurs in similar associations with the malachite. It is however rarer.

### 59. *Zinc Blende.*

Blende is found in considerable quantity, both massive and crystallized. Some of the crystals are exceedingly beautiful, and of large size, being three or four inches in diameter, and with very brilliant surfaces. The colors are dark hair-brown and black, the brown being transparent. The specimens from this locality are hardly surpassed by those from any other mine. A specimen that was analyzed gave the following results: —

| | |
|---|---|
| Sulphur, | 33.82 |
| Zinc, | 64.39 |
| Cadmium, | .98 |
| Copper, | .32 |
| Lead, | .78 |
| | 100.29 |

It is proposed to examine yet other specimens, to see if there may not be larger amounts of cadmium contained in some of them.

This mineral occurs in fluor spar, calc spar, and quartz, more or less mixed with the other sulphurets. In some instances it is very peculiarly interlaced in the rocks; thus we have specimens consisting as it were of four layers; namely, granite, then compact crystallized quartz three fourths of an inch thick, then the blende an inch thick, on that a layer of crystals of calc spar, and on this last fluor spar.

### 60. *Calamine.*

Calamine is found in delicate crystals of a silky lustre, forming in some instances snow-white tufts on fluor spar, blende, and carbonate

of lime. It is also found on cellular quartz. Some of the specimens are quite handsome, having a blue and yellow color from the presence of carbonate of copper and oxide of iron. No analysis was made of any of the specimens.

### 61. *Brown Hematite.*

This ore occurs in concretionary masses, of a dark liver-color and compact structure, associated with nearly all the minerals of this mine. It very commonly forms a lining to cavities in galena, in which are found crystals of anglesite and cerusite; sometimes it lines cavities in the rock that are completely filled with cubical galena. Acicular concretions of the hematite are found traversing crystals of anglesite and cerusite. A specimen of the purest hematite gave for its composition,

| | |
|---|---|
| Peroxide of iron, . . . . . . . | 80.32 |
| Oxide of copper, . . . . . . | .94 |
| Oxide of lead, . . . . . . . | 1.51 |
| Water, . . . . . . . . | 14.02 |
| Silica, . . . . . . . . . | 3.42 |
| | 100.21 |

### 62. *Fluor Spar.*

The remarkable feature of the fluor spar of this mine is the absence of color, all the specimens yet found being colorless and transparent. The crystals are very perfect and beautiful, yet small; it is sometimes in globular concretions, of crystalline structure radiating from the centre. The cube, which is the more common crystalline form, is sometimes very much modified by the truncation of the edges and angles. A specimen that was examined gave a specific gravity of 3.15, and the following composition: —

| | |
|---|---|
| Fluorine, . . . . . . . . . | 48.29 |
| Calcium, . . . . . . . . | 50.81 |
| Phosphate of lime, . . . . . . | *trace.* |
| | 99.10 |

It is associated with calc spar, and in some instances in a remarkable manner, mentioned under the head of calc spar. Galena and blende are interspersed through it. Its occurrence in the mine was

first noticed at the depth of three hundred feet, and since then it has been found abundantly.

### 63. *Calc Spar.*

There are a variety of interesting forms and associations of this mineral. The two most common are the dog-tooth spar and the hexagonal prism with a three-sided summit, and occasionally the hexagonal prism with flattened summits like arragonite. Sometimes slabs of this mineral are found, with a surface of eight or ten square feet completely covered with prismatic crystals an inch or two in length, and from half an inch to an inch in thickness; they are mostly vertical, but occasionally horizontal, with double terminations. These crystals are sometimes of a remarkable character, being eight or ten inches in length, and only a quarter of an inch in diameter, preserving a tolerably perfect hexagonal shape throughout the entire length; again, these slender forms are built up of small hexagonal prisms, their faces projecting from the side. It sometimes happens that these slender crystals are crossed by one of the same diameter, and less length, firmly attached in the manner of a cross.

But of all remarkable crystallizations is one where the small prisms are so arranged as to form a perfect double spiral arranged around an axis (Fig. 3); the specimen is three inches in length, and three

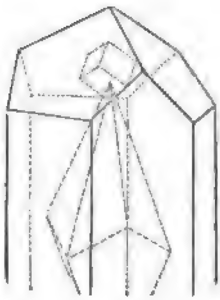
3.

eighths of an inch in diameter, with the space of a fourth of an inch between each turn of the spiral. The spiral arises from one small prism, crossing another at middle at a small angle of divergence (40° - 50°), and so on in succession. These slender crystals are sometimes curved in a very remarkable manner.

Another thing to be remarked in connection with the calcite of this mine is its singular associations; thus, we find groups of hexagonal prisms where a small cubical crystal of fluor, about the twentieth of an inch, is inserted in a small pit in the summit of almost every crystal (Fig. 4), without the occurrence of fluor spar on any other parts of the crystal. These crystals appear to have been formed

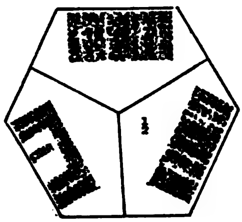
by successive crystallizations. Dog-tooth spar seems to have been first formed with these small crystals of fluor spar on their extremities, and then by a subsequent process the calcite has closed around the dog-tooth spar in the form of an hexagonal prism with a three-sided summit. The summit never closes entirely at the centre, the fluor spar remaining visible on one side, and where there is no crystal of fluor spar, the extremity of the dog-tooth spar is frequently seen.

4.



Other groups of calcite crystals have minute crystals of iron pyrites in the three faces of the summit, arranged near and perfectly

5.



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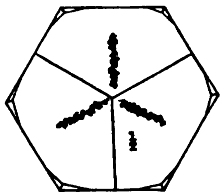

parallel to the alternate edges, as seen in Fig. 5. Every crystal in the group is thus furnished with a set of crystals of pyrites.

In another group of crystals, the pyrites, in equally small crystals, is found in three lines on the summit of every crystal, running from the apex towards the edges, exactly bisecting each face, as seen in Fig. 6.

In this instance, as well as in the former, the pyrites is inserted entirely beneath the surface of the crystal, which is perfectly smooth.

The calcite is found in large crystals in dolomite, and is associated with most of the ores of the mine. It sometimes gives rise to pseudomorphs of molybdate of lead and carbonate of lead; these pseudomorphs are mere shells, however, retaining the form of the calcite.

### 64. *Sulphur*.

Sulphur occurs in the form of small pale greenish-yellow crystals; they are transparent, and disseminated through cellular galena, which appears to have undergone partial decomposition; the galena in which it occurs is frequently associated with copper and iron pyrites, and in some rare instances with carbonate and phosphate of lead.

The other minerals occurring in the Wheatley mine are finely crystallized *quartz*, *oxide of manganese*, *iron pyrites*, *sulphate of baryta*, *indigo copper*, *black oxide of copper*, and *dolomite*.

Of the other mineral veins in this region, none have yielded the beautiful mineral species furnished by the Wheatley vein. The Perkiomen vein, five miles from the Wheatley vein, has furnished fine *capillary copper*, *indigo copper*, fine acicular crystals of *sulphate of baryta*, *crystallized copper*, and some crystals of *sulphate*, *carbonate*, and yellow *molybdate of lead;* but these last were small, and bear no comparison to those described.

It was hoped that something might be learned concerning the formation of the minerals of this vein, but the difficulties and uncertainty attendant upon the study of questions of this kind make it prudent to postpone any views that might be suggested. It may, however, be well to remark, that, in opening the vein, and descending from the surface for the first thirty feet, the phosphate of lead was very abundant, with some galena and carbonate; a little lower down, the phosphate was less, and the carbonate more abundant. Wulfenite and anglesite began to appear at 120 feet; the phosphate and carbonate still continued with the galena, with fine large crystals of anglesite, and considerable wulfenite; at 180 feet, phosphate very much diminished, carbonate and sulphate in fine crystals; arsenate was found here; at 240 feet, blende, calamine, and fluor spar appear, with considerable dolomite, and but little phosphate of lead, galena forming almost the whole lead ore; anglesite is found, but in smaller crystals. These observations may hereafter lead to some conclusions as to the manner of the formation of these minerals, but at present I prefer dismissing the subject without further remarks.

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## III. GEOLOGY.

### 1. Remarks on some Points connected with the Geology of the North Shore of Lake Superior. By J. D. Whitney.

(*Abstract.*)

The object of this communication was to give a sketch of the results of observations made by the author on the north shores of Lake

Superior and Lake Huron, during a portion of two seasons after the completion of the geological survey, by Mr. Foster and himself, of that part of the southern shore which is included in the Lake Superior Land District. Apart from the scientific interest attaching to an examination of the northern shore of this lake, it became a matter of great practical importance that the analogy between the rocks of the two sides of the lake should be studied, with reference to the probable value of the cupriferous veins which were known to exist, and which have been more or less extensively worked at various points on the Canadian side of Lake Superior, but nowhere with that success with which they have been, and are now, wrought within the territory of the United States.

The northeastern side of the lake, from Gros Cap, near its outlet, to the northeastern corner of Neepigon Bay, is formed by rocks of the azoic system. Occasional outliers and detached portions of the Lake Superior sandstone, forming the base of the palæozoic system of the Northwest, lie along the shore; and most of the large islands at this end of the lake, with the exception of Michipicoten, show nearly horizontal strata of the same rock, indicating that the basin of the lake in this direction was once covered with sandstone, which has since been removed by denudation. Thus the lake basin may be divided into two portions by a line drawn from Keweenaw Point to Michipicoten Island; that to the north owes its form to the existence of an axis of depression between two parallel lines of elevation, running nearly northeast and southwest, and from 50 to 60 miles distant from each other; while that portion which lies to the south has been simply scooped out by the action of water. The considerably diminished depth of the southeastern part of the lake, as compared with the northern and central portions, would appear to confirm this opinion, although the soundings which have been taken as yet are not sufficiently numerous to show the exact shape of the bottom of the lake.

From Saut Ste. Marie, following the south shore in its whole extent, and along the north side as far east as the northeastern extremity of Neepigon Bay, we find exposed on the lake shore only shales, sandstones, and conglomerates, the equivalent of the Potsdam sandstone, and the accompanying trappean rocks, with the exception of the north side of Thunder Bay and the vicinity of Carp River, where the lake

has its extreme southern extension. At each of these points the sandstone has been washed away, so as to allow the azoic to make its appearance along the lake shore for a distance of a few miles. An almost straight line drawn northeast and southwest from the northeast corner of Neepigon Bay, along the north side of Thunder Bay, crossing the Kamanistiquia River at Kakabeka Falls, and Pigeon River at the falls of the same name, and keeping nearly parallel with, and a few miles distant from, the coast of the lake from this point westward, marks the southern limit of the azoic on the north side of the lake. An inspection of the map of Lake Superior will show how marked has been the influence of this line of upheaval in determining the general outline of the lake on this side. On the south side the northern line of the azoic still preserves an approximate parallelism with the shore; but a belt of sandstone and trap much wider than that on the other side interposes between it and the lake, and the axis of depression becomes less and less marked towards the west.

Similar as are the north and south shores of the lake in the general features of their geology, the details of the structure which they exhibit are very different. The most important distinction between the two shores is in the character of the igneous masses which accompany the sedimentary rocks. On the south side we have gently curving bands of trappean rock, of quite regular thickness and persistent in lithological character, which usually extend for many miles uninterruptedly. Thus, the great greenstone ridge of Keweenaw Point may be followed for more than forty miles, forming the most conspicuous feature in the topography of the region, and everywhere underlaid by a band of conglomerate, which, though only a few feet in thickness, extends with perfect regularity from the extremity of the Point to beyond the Cliff Mine. There are but few cross-fractures, slides, or heaves of the beds of rock upon this side of the lake, and no dykes whatever from one end of the region to the other. On the other side, the change in this respect in the character of the igneous rocks is most marked. Isle Royale, lying from 15 to 20 miles in advance of the entrance to Thunder Bay, is mostly made up of bedded traps, and is the counterpart of the north side of Keweenaw Point. The beds of rock are, however, usually thin, and very varying in lithological character, and the same is true of Michipicoten Island, although to a somewhat less extent. That part of the northern coast which belongs to the Territory

of Minnesota is quite regular in its general outline, and has but few islands in advance of it; it is made up of bands of slates and sandstones, which are often much hardened and changed in character, and which alternate with bedded traps and volcanic grits. The whole system has a dip towards the lake, as on the south side. The great number of dykes which intersect the bedded traps and sandstones in this region form a marked feature in its geology, and one which differs from anything exhibited on the southern shore. The beds of rock being thin, and greatly disturbed by the dykes, are with difficulty traceable for any considerable distance.

As we approach Pigeon River, which forms the boundary between Minnesota and Canada, and which is nearly opposite the western end of Isle Royale, the shore of the lake becomes very irregular in its outline, and deeply indented by bays, and forms lofty and precipitous cliffs, which display some of the most picturesque and striking scenery of the Northwest. Between Pigeon River and Fort William the region bordering on the lake is exceedingly broken, and rises in precipitous ranges, sometimes to the height of 1,000 feet above the lake. They have a trend rudely parallel with that of the coast, but are very irregular in their outline. The rock of which they are composed is a trap, usually hard and crystalline, resembling that of the southern range of Keweenaw Point. It is frequently traversed by vertical planes of cleavage, so as to assume a columnar structure, and occasionally it takes on the appearance of a trap shale, being readily separated into flat plates or laminæ by horizontal lines of division. McKay's Mountain and Pie Island are two of the most conspicuous landmarks of this region. Thunder Cape is the most elevated point on the shores of Lake Superior, and one of the most interesting. It consists of a narrow ridge from four to five miles in length, elevated in its highest point about 1,350 feet above the lake. Very thinly bedded slates or shales of a dark color, and somewhat argillaceous, which sometimes divide into sheets as thin as paper, make up nearly 800 feet of the thickness of this mass. These slates, which lie nearly horizontally, are capped by a sheet of trappean rock from 200 to 300 feet in thickness. This elevation occupies the extremity of the neck of land, which runs in a northwest and southeast direction, and separates Black from Thunder Bay. A few miles east of the extremity of the point of Thunder Cape, the rock exposed along the shore is sand-

stone, which dips from 10° to 15° to the southeast, and is made up of buff and red layers, which are rather thinly bedded. The dark slates of Thunder Cape seem to be only a local modification of the sandstone, similar to that which occurs at Black and Presqu' Isle Rivers on the south shore, where a dark-colored, highly fissile slate passes gradually into the usual light-colored, heavy-bedded sandstone of the region. In the isolated precipitous knobs and ridges of the trap in this region we see the evidence of very considerable displacements of the rocks along lines of fracture, extending nearly northeast and southwest, and of secondary shorter lines at right angles to this direction. There are also marks of powerful denudation, and to this cause, as well as to the shortness and abruptness of the lines of elevation, the broken and irregular form of the coast must be ascribed. The peninsulas which separate Thunder Bay from Black Bay, and the last named from Neepigon Bay, are low, and show strata of sandstone dipping gently to the southeast. If the surface of the lake were elevated a few feet, probably not more than a hundred, these bays would all become connected with each other, and this part of the lake shore would extend, in a nearly regular line, from northeast to southwest, having in front of it, at a distance of 10 or 15 miles, a range of lofty and precipitous islands, of which what is now Thunder Cape would be the most conspicuous.

The distance to which the trap and sandstone formation extends towards the northeast from the northern extremity of Neepigon Bay is not known. A few miles up Neepigon River, which runs into the bay at its northwest angle, cliffs of trap, from 700 to 800 feet high, may be observed resting on beds of red and somewhat argillaceous sandstone. From the summit of these cliffs, looking to the northeast, the same kind of formation seems to extend to a considerable distance. St. Ignace, Simpson's, and the Vein Islands, which lie in front of Neepigon Bay, are made up of alternating beds of trappean rock and sandstone, with some conglomerate, and resemble Isle Royale in their lithological character.

Veins have been opened and worked on the east side of the lake in the azoic, and on the north side in the trap accompanying the Lake Superior sandstone, and numerous indications of copper have been observed at various points along the whole line of the shore. So far as is known, there are no mines now in operation on the Canada

side, nor have there ever been within the borders of Minnesota. On Lake Huron, however, mining has been and is now carried on to a considerable extent in the azoic, with fair prospects of success.

As a general rule the following is true of the metalliferous veins on both sides of the lake. In the azoic the veins have purely quartzose gangues, and bear copper pyrites and the sulphurets of copper, with some sulphuret of iron. In the unbedded traps, which have been protruded among the alternating beds of trap and sandstone, as in the south range of Keweenaw Point and the ranges northwest of Isle Royale, the ores are sulphurets of copper and copper pyrites, with considerable sulphuret of zinc, and occasionally native silver, while the gangues are chiefly calcareous spar and heavy spar. Of the latter mineral there are numerous heavy veins; but when either this veinstone or calcareous spar occurs unmixed with quartzose matter, they rarely carry any traces of ore. In the bedded trappean rocks and the interstratified conglomerates, copper and silver occur almost solely in the native state, and are accompanied by zeolitic veinstones mixed with quartz and calc spar. And it is this latter class of veins only in which large and profitable mines have thus far been wrought. In these, regularity and thickness of the beds of igneous rock seem to have been necessary for the formation of largely productive and well-developed veins. When the beds of rock are thin, rapidly changing their lithological character, brecciated in their structure, or deranged by irregular upheaval and frequent cross-fractures, the veins have been rarely found rich in metallic contents. In the unbedded trap, which is frequently very crystalline, and has sometimes a porphyritic structure, the veins are sometimes very wide and regular, but the ore is always very sparsely disseminated through the veinstone, and they have not, in any instance, been worked with profit.

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## 2. On the Occurrence of the Ores of Iron in the Azoic System. By J. D. Whitney.

The object of the present communication is to call attention to the geological position and mode of occurrence of one of the most interesting and important classes of the ores of iron, namely, those which are associated with rocks of the azoic system.

The term AZOIC, first applied by Murchison and De Verneuil in their description of the geology of the Scandinavian Peninsula, has been adopted by Mr. Foster and myself in our Reports on the Geology of the Lake Superior Land District, and has been shown by us to be applied with propriety to a series of rocks which covers an immense space in the Northwest. We have called attention to the fact, that this system of rocks, wherever it has been demonstrated to exist, has been found characterized by the presence of deposits of the ores of iron, developed on a scale of magnitude unlike anything which occurs in any of the succeeding geological groups or systems of rocks.

As illustrations of these views, we have briefly described some of the great ferriferous districts of the world, and particularly those of Lake Superior, Scandinavia, Missouri, and Northern New York, all of which exhibit the most marked analogy with each other, both in regard to the mode of occurrence and the geological position of the ores. The two last-named regions, however, not having been thoroughly examined by us in person, we were obliged to content ourselves with information obtained from others, in making a comparison of their most striking features.

Strongly impressed with the interest attaching to this subject, I availed myself of the first opportunity, after the publication of our Report, to visit the iron regions of Missouri and Northern New York, from the last-named of which I have just returned, after a careful examination of the most important localities where ore is now mined in that district. While it is intended to take another opportunity for giving a minute and detailed account of this region, it may be permitted to recapitulate here the principal points maintained by Mr. Foster and myself, and to the general correctness of which my more recent explorations have furnished me with additional evidence.

We maintain, therefore, —

1. That deposits of the ores of iron exist in various parts of the world, which in extent and magnitude are so extraordinary as to form a class by themselves. The iron regions mentioned above offer the most striking examples of the deposits now referred to.

2. That the ores thus occurring have the same general character, both mineralogically and in their mode of occurrence, or their relations of position to the adjacent rocks.

3. That these deposits all belong to one geological position, and are characteristic of it.

The extent of the workable deposits of the ores of the useful metals is usually quite limited. Most of the veins which are wrought in mines throughout the world are but a few feet in width, often not more than a few inches. This is true of the ores occurring in veins. In sedimentary metalliferous deposits, such as those of the ores of iron in the carboniferous, the horizontal extent is often very considerable; but the vertical range is so limited, that the most extensive basins may be in time exhausted, when worked on so extensive a scale as is the case in some of the celebrated iron districts of Great Britain. The deposits of iron in the azoic, however, are many of them developed on such a scale of magnitude, that the term "mountain masses" may be applied to them without exaggeration, while, from the very nature of their occurrence, they must extend indefinitely downwards, and cannot be exhausted. Thus the great iron mountain of Gellivara, in Sweden, has a length of three or four miles, and a width of not less than a mile and a half. Of course such a mass of ore, without limit in depth, might be worked on the most enlarged scale for any length of time without fear of exhaustion. The same may be said of some of the iron knobs and ridges of Lake Superior and of Missouri. They form veritable mountains of ore, and ages must elapse before their dimensions will have been perceptibly diminished. This is not necessarily the case with all the localities of ore of these districts. Indeed, in Northern New York and in Scandinavia, although there are accumulations of iron which may be measured by hundreds of feet, or even by miles, yet those which are best known and most worked are of much more reasonable dimensions.

The character of the ores thus occurring is mineralogically peculiar. They consist uniformly of the oxides, either the magnetic or the specular. Hydrous ores, carbonates, and the like are altogether wanting, unless it be upon the borders of the ore deposits, where a secondary metamorphic action between the ferriferous mass and the adjacent rocks may have taken place. The oxides found in this geological position are in general remarkably free from all injurious substances, such as sulphur, arsenic, lead, or zinc, and usually the approach to chemical purity in the ores is in proportion to the extent of the mass, the largest deposits being the purest. The principal foreign ingre-

dient mixed with these ores is silica, which is always present, although frequently in minute quantity. Indeed, the analyses of the Lake Superior and Missouri ores show, in some instances, a surprisingly near approach to a state of absolute purity. It would not be difficult in some localities to procure large quantities of an ore not containing more than two or three tenths of one per cent of foreign matter, and that exclusively silica. The purity of the ores may be inferred from the high character and value of the iron manufactured from them when they have been skilfully worked, as, for instance, in Sweden. Some samples of iron manufactured from Lake Superior ore have, when tested, exhibited a degree of tenacity unequalled by that from any other part of the world. The ores of Lake Superior and Missouri are mostly peroxides; those of Northern New York almost exclusively magnetic; while in Scandinavia the magnetic and specular ores are both of frequent occurrence. Those of New York, on the one hand, are often coarse-grained and highly crystalline, while the peroxides of Lake Superior and Missouri are rarely distinctly crystallized, but are very compact.

The mode of occurrence of these ores in the regions above mentioned is so peculiar, that, from this point of view alone, it is apparent that these deposits should be classed together as distinct from those in the later geological formations. In all the characteristics of true veins, the great masses of ore now under consideration are wholly wanting. Some of the least important of them approach much nearer to segregated veins, and might with propriety be classed with them, were they not developed on so large a scale as to render it difficult to conceive of segregation as a sufficient cause for their production.

In the case of the most prominent masses of ore of these regions, there is but one hypothesis which will explain their vast extent and peculiar character. They are simply parts of the rocky crust of the earth, and, like other igneous rocks, have been poured forth from the interior in the molten or plastic state. No other origin can be assigned to the dome-shaped and conical masses of Lake Superior and Missouri, or to the elongated ridges of the first-named region. The Iron Mountain of Missouri forms a flattened dome-shaped elevation, whose base covers a surface of a little less than a square mile, and which rises to a height of 200 feet above the general level of the adjacent country. The surface of the mountain, when uncovered of the soil,

is found to be covered with loose blocks of peroxide of iron, without any admixture of rocky pebbles or fragments, which are found to increase in size in ascending to the summit, where large blocks of ore of many tons in weight lie scattered about, and piled upon each other. It is a most singular fact, that the ore is nowhere seen in place about the mountain, although the whole mass evidently consists of nothing else. Near its base, an excavation seventeen feet deep has been made, which exhibits nothing but small, somewhat rounded fragments of ore closely compacted together, without any other substance being present except a little red, ferruginous clay, which seems to have been formed by the friction of the masses against each other. This feature in the Iron Mountain is one of peculiar interest, and one which it seems difficult to explain. Evidences of drift action in this region are exceedingly faint. The ore itself is one which seems little likely to undergo decomposition from any exposure to atmospheric changes. The blocks upon the summit, although somewhat moss-grown, have their angles and edges but little rounded. As a key to the origin of the ore, we find in close proximity on the north a long elevation of a reddish porphyry of unmistakably eruptive character, connected with the Iron Mountain by a narrow ridge of a rock composed of iron ore and feldspathic rock, showing that the porphyritic ridge and the ore-mass must have originated at one and the same time, and in the same way.

The eruptive origin of the great Lake Superior ore-masses seems also well sustained by the phenomena which they exhibit. They alternate with trappean ridges whose eruptive origin cannot be doubted, and which, themselves, contain so much magnetic oxide disseminated through their mass, as one of their essential ingredients, that they might almost be called ores. These eruptive masses include the largest and purest deposits of ore which are known in the Lake Superior or the Missouri iron regions; but there are other localities in both these districts where the mode of occurrence of the ore is somewhat different, and where the evidences of a direct igneous origin are less marked. This class comprehends those lenticular masses of ore which are usually included within gneissoidal rocks, and whose dip and strike coincide with that of the gneiss itself, but whose dimensions are limited. Such is the character of most of the Swedish deposits, and of many of those of Northern New York. Such beds of ore as these

may in some cases be the result of segregating action; but the facts seem rather to indicate that they are made up of the ruins of pre-existing igneous masses, which have been broken and worn down during the turbulent action which we may suppose to have been pre-eminently manifested during the azoic epoch, and then swept away by currents, and deposited in the depressions of the sedimentary strata then in process of formation. In confirmation of this hypothesis in regard to the origin of these lenticular masses of ore in the gneissoidal rocks, it may be noticed that the ores occurring in this form and position are less pure than those of decidedly igneous origin, as if they had become more or less mixed with sand during the process of re-construction, so that they not unfrequently require to be separated from their earthy impurities by washing before they can be advantageously used. Again, it may be observed in the case of some of the ore-beds of this class, that the bed-rock or foot-wall is considerably rougher or more irregular in its outline than the hanging wall or roof, as if depositions had taken place upon a surface originally rough and uneven, the upper surface of the ore being considerably smoother and more regular than the lower one, and sometimes separated from the rock above by a thin seam of calcareous matter.

There is still another form of deposit which is not unfrequently met with in the Lake Superior region, and which may be seen on a grand scale in the Pilot Knob of Missouri. This consists of a series of quartzose beds of great thickness, and passing gradually into specular iron, which frequently forms bands of nearly pure ore, alternating with bands of quartz more or less mixed with the same substance. Some of the deposits in the Lake Superior region are of this class, and they are very extensive, and capable of furnishing a vast amount of ore, although most of it is so mixed with silicious matter as to require separating by washing before use. Heavy beds of nearly pure ore occur at the Pilot Knob, interstratified with beds of a poorer quality. Deposits of this character are usually very distinctly bedded, and the ore shows a greater tendency to cleave into thin laminæ parallel with the bedding, in proportion to its freedom from silicious matter. These deposits seem to have been of sedimentary origin, having been originally strata of silicious sand, which has since been metamorphosed. The iron ore may have been introduced either by the sublimation of metalliferous vapors from below during the deposition of

the silicious particles, or by precipitation from a ferriferous solution, in which the stratified rocks were in process of formation.

The great deposits of ore which have been alluded to above, all agreeing as they do in the characteristic features of their mode of occurrence, especially in the magnitude of the scale on which they are developed, are all, beyond a doubt, situated in the same geological position; they all belong to the oldest known system of rocks, the azoic. This name was first applied by Murchison to the ferriferous rocks of Scandinavia, and the geological position of the great iron regions of this country is precisely similar to those of Sweden. There is ample evidence that the lowest known fossiliferous strata, characterized by the same peculiar types of organic life, both in this country and in Europe, rest uniformly upon the iron-bearing strata throughout the Northwest, from New York to Missouri and Arkansas.

We have thus seen that the earliest geological epoch was characterized by the presence of the ores of iron in quantity far exceeding that of any succeeding one; indeed, we may infer that the ruins of the iron ores of this class have furnished the material from which many of the ores of more recent geological age may have been derived. The condition of things in reference to the ores of iron which existed during the azoic period underwent a complete change, and rarely do we find in any fossiliferous rocks any signs of unmistakably eruptive ores. It is certain that we nowhere out of the azoic system find masses of ore of such extent and purity as those which have just been alluded to. By far the larger portion of the azoic series on the earth's surface being covered up by the fossiliferous rocks, the ore which that formation contains is equally concealed, and it is only in those regions where no deposition of newer strata upon the oldest rocks has taken place that the treasures of iron are made accessible. In this respect, our country is pre-eminently favored, and there can be no doubt that the immense deposits of iron ore stowed away in the Northwest are destined at some future time to add to our national wealth more than has been or ever will be contributed by the gold of California. It may seem absurd to speculate on the exhaustion of the stratified ores of England or of the Eastern United States; yet nothing is more certain, than that the present rate of production in the former country cannot be kept up for any very great length of time, without

making the cost of procuring ore so great, that other regions which now seem very remote from a market will be able to compete with the most favored iron-producing districts of England.

Practically, the views which have been presented above are of importance, as leading us to expect large and valuable deposits of the ores of iron wherever the azoic rocks are found to exist over any considerable surface. Thus it may safely be predicted that important discoveries of ore will be made in the now almost unexplored regions of British America, which are covered by rocks of the azoic period. Indeed, large beds of ore have already been found in Canada, which are, in character and position, analogous to those of Northern New York.

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## 3. On the Grooving and Polishing of Hard Rocks and Minerals by Dry Sand. By William P. Blake, of Washington.

The phenomena about to be described were observed in the Pass of San Bernardino (California), in 1853.* This pass is one of the principal breaks through the southern prolongation of the Sierra Nevada, and connects the Pacific slope with the broad and low interior plain of the Colorado Desert. It is bounded on each side by high mountains; the peak of San Bernardino rising on the north to the height of about 8,500 feet, and San Gorgonio on the south to about 7,000. The elevation of the summit-level is 2,808 feet above the Pacific, and the width of the gap at that point is about two miles; from this the ground slopes each way very gradually, the grade or descent on the east, for about 28 miles, being on an average 69 feet per mile.

On this eastern declivity of the pass, — the side turned towards the desert, — the granite and associate rocks which form the sharp peak of San Gorgonio extend down to the valley of the pass in a succession of sharp ridges, which, being devoid of soil and of vegetation, stand out in bold and rugged outlines against the clear, unclouded sky of that desert region.

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* A brief notice of these phenomena is given in the writer's Preliminary Geological Report, accompanying the Report of Lieutenant R. S. Williamson of a reconnoissance in California. House Doc. 129, p. 27. Washington, 1855.

It was on these projecting spurs of San Gorgonio that the phenomena of grooving were seen. The whole surface of the granite, over broad spaces, was cut into long and perfectly parallel grooves and little furrows, and every portion of it was beautifully smoothed, and, though very uneven, had a fine polish. For a moment it was impossible to realize the cause of all this abrasion, performed in a manner so peculiar. The action of glaciers and drift was thought of in succession; but the appearance of the surface was so entirely different from that of rocks which have been acted on by these agents, that I could not regard them as the cause. While contemplating these curious effects, the solution of the problem was presented. The wind was blowing very hard, and carried with it numerous little grains of sand. When I stooped down and glanced over the surface of the rocks, I saw that they were enveloped in an atmosphere of moving sand, which was passing over and accumulating in deep banks and drifts on the lee side of the point. Grains of sand were thus pouring over the rocks in countless myriads, under the influence of the powerful current of air which seems to sweep constantly through this pass from the ocean to the interior.

Wherever I turned my eyes, — on the horizontal tables of rock, or on the vertical faces turned to the wind, — the effects of the sand were visible: there was not a point untouched, — the grains had engraved their track on every stone. Even quartz was cut away and polished; garnets and tourmaline were also cut, and left with polished surfaces. Masses of limestone looked as if they had been partly dissolved, and resembled specimens of rock-salt that had been allowed to deliquesce in moist air. These minerals were unequally abraded, and in the order of their hardness; the wear upon the feldspar of the granite being the most rapid, and the garnets being affected least. Wherever a garnet or a lump of quartz was imbedded in compact feldspar, and favorably presented to the action of the sand, the feldspar was cut away *around* the hard mineral, which was thus left standing in relief above the general surface. A portion, however, of the feldspar on the lee side of the garnets, being protected from the action of the sand by the superior hardness of the gem, also stood out in relief, forming an elevated string, osar-like, under their lee.

When the surface acted on was vertical, and charged with garnets, a very peculiar result was produced; the garnets were left standing in

relief, mounted on the end of a long pedicle of feldspar, which had been protected from action while the surrounding parts were cut away. These little needles of feldspar, tipped with garnets, stood out from the body of the rock in horizontal lines, pointing, like jewelled fingers, in the direction of the prevailing wind. They form, in reality, a perfect index of the wind's direction, recording it with as much accuracy as the oak-trees do in the regions about San Francisco, where they are all bent from the perpendicular in one direction, or in some places lie trailed along the ground. All these little fingers of stone pointed westward, in the direction of the valley of the pass, to which the wind conforms. We experienced this wind before reaching the point of rocks and the sand-drifts; it blew with great force, and seemed to be a great air-current, as uniform in its direction and action as the great currents of the sea. It flows into the interior with singular persistence and velocity, sweeping down over the slope of the pass, not in fitful gusts and eddying whirls, but with a constant uniformity of motion, unlike any of the winds of our Atlantic seaboard, or of the plains.

The pass would in fact appear to be a great draught-channel or chimney to the interior, through which the air rushes inland from the cool sea, to supply the vacuum caused by the ascent of a column of heated air from the parched surface of the great Desert. This pass is the only break of any magnitude in the mountain chain for a long distance, and, as an air-channel, holds the same relation to the Colorado Desert as is sustained by the Golden Gate at San Francisco to the broad interior valleys of the Sacramento and San Joaquin.

The effects of driving sand are not confined to the pass; they may be seen on all parts of the Desert, where there are any hard rocks or minerals to be acted upon. On the upper plain, north of the Sand Hills, where steady and high winds prevail, and the surface is paved with pebbles of various colors, the latter are all polished to such a degree that they glisten in the sun's rays, and seem to be formed by art. The polish is not like that produced by the lapidary, but looks more like lacquered ware, or as if the pebbles had been oiled or varnished.

On the lower parts of the Désert, or wherever there is a specimen of silicified wood, the sand has registered its action. It seems to have been ceaselessly at work, and where no obstacle was encountered on which wear and abrasion could be effected, the grains have acted on

each other, and by constantly coming in contact have worn away all their little asperities, and become almost perfect spheres. This form is evident when the sand is examined by a microscope.

We may regard these results as most interesting examples of the denuding power of loose materials transported by currents in a fluid. If we can have a distinct abrasion and rectilinear grooving of the hardest rocks and minerals, by the mere action of little grains of sand falling in constant succession, and bounding along on their surface, what may we not expect from the action of pebbles and boulders of great size and weight transported by a constant current in the more dense fluid, water? We may conclude that long rectilinear furrows, of indefinite depth, may be made by loose materials, and that it is not essential to their formation that the rocks and gravel, acting as chisels or gravers, should be pressed down by violence, or imbedded in ice, or moved forward *en masse* under pressure by the action of glaciers or stranded icebergs. Wherever, therefore, we find on the surfaces of mountains, not covered by glaciers, grooved and polished surfaces, with the furrows extending in long parallel lines, seeming to indicate the action of a former glacier, we should remember the effects which may be produced during a long period of time by light and loose materials transported in a current of air; and which consequently may be produced with greater distinctness, and in a different style, by rocks moved forward in a current of water. The effects produced by glaciers, by drift, or moving sand, are doubtless different and peculiar, — so different and characteristic, that the cause may be at once assigned by the experienced observer, who can distinguish between them without difficulty. It is, however, possible, that, after a sand-worn surface, such as has been described, has been for ages covered with moist earth, a decomposition of the surface would take place, sufficient to remove the polish from the furrows, and leave us in doubt as to their origin.

If it were possible, it would be exceedingly interesting to ascertain the length of time it has required for the little grains of sand to carve the surface of the granite ridge to its present form. How inappreciably small must be the effect produced by a single grain! And yet by their combined and long-continued action mighty effects are produced. That the action of the grains singly is not visible, is proved to us by the polished surface, for no one grain cuts deeply enough to leave a scratch.

Ages have, doubtless, elapsed since this action of the sand began, and we cannot tell how deep the abrasion has extended; cubic yards of granite may have been cut into dust, and driven before the wind over the expanse of the Desert.

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## 4. Observations on the Characters and Probable Geological Age of the Sandstone Formation of San Francisco. By William P. Blake, of Washington.

(*Abstract.*)

The hills upon which the city of San Francisco is built are formed of regularly stratified sandstone, in thick beds, alternating with shales. This sandstone has many interesting peculiarities, being very hard, and of a dark bluish-green color in the interior portions; when exposed to the air and moisture, it rapidly changes, becomes rusted and brown, and is much softened. It is therefore not very suitable for building, and yet in dry situations will form a very durable wall.

These strata crop out in different parts of the city, and have been exposed by street cuttings; they have also been exposed by several quarries on the islands near the city and around the bay. These openings show that the strata are much uplifted; they dip at all angles, from 20 to 60 degrees, and appear to be thrown into great wave-like flexures. Several small faults and dislocations of the beds were seen in different places, and show that the formation has been greatly disturbed.

This sandstone is compact, fine-grained, and hard; it is not easily crumbled, and is quite tough. After long exposure, however, it may be crumbled by the fingers on the edges of the blocks. All the specimens that I examined contained a notable quantity of carbonate of lime. Iron pyrites was also observed. The sandstone and the shales are filled with numerous thin black films, or small patches, which appear to be of vegetable origin. In the sandstone they have the characters of a hard and dark slaty clay; in the shale, however, masses of similar form are distinctly carbonaceous.

I have not been able to obtain any fossils in the quarries about San Francisco, or to find any in the outcrops of the strata. At Benicia,

however, there are similar sandstones; and I there found casts of *Turritella*, and a shark's tooth which Professor Agassiz has recognized as of the genus *Lamna.* These strata are much softer than the beds at San Francisco, but they are also much uplifted, and some hard, undecomposed blocks were seen, which greatly resemble the sandstone of Yerba Buena Island, opposite the city. I am therefore of the opinion that the Benicia strata belong to the formation developed around San Francisco. South of Benicia, around the base of Monte Diablo, similar strata are abundantly developed; and at one point I found imperfect casts of a species of *Cardium.* I have obtained also a block of sandstone from the coal formation of Bellingham Bay, which in its mineral characters resembles very closely the San Francisco rock. It contains fragments of coal, and impressions of coal plants, and has two large, well-preserved shells of the genus *Pecten* imbedded in it.

With these facts in view, I have been induced to regard the San Francisco sandstone as of *Tertiary age*, although I have found it difficult to so regard it by reason of the peculiar hardness and compact character of the strata, which more closely resemble the older palæozoic formations than ordinary Tertiary.

I have recently procured additional evidence of the age of these rocks from several fossil *Spatangi* which were washed up by the surges of the Pacific on the beach of the western side of the San Francisco peninsula. I present it here, with the hope that Professor Agassiz may be able to assign its age.

These Spatangi are thrown up in considerable quantities, though it is difficult to obtain perfect specimens. The color and mineral characters of the investing rock are so nearly identical with those of the sandstone around the city, that I do not hesitate to regard the fossils as broken from submarine outcrops of the strata.

Between San Francisco and the Pacific there is a high ridge of serpentinoid or magnesian rock, which is flanked on both sides by the sandstone, and which appears to be eruptive. A mass of sandstone and shale, about 300 feet thick, is imbedded in this serpentine.

A belt of hard, flinty, or jasper rocks crops out near the Presidio; they are distinctly stratiform, and dip at a high angle. They are charged with irregular veins of white quartz. These rocks are probably metamorphosed portions of the sandstone formation. Similar rocks are largely developed at Lime Point and at San José. At the

San Juan Mountain, on the road to Monterey, there are also heavy strata of sandstone, highly inclined, and resting on granite; which is also the case at San José.

It would therefore appear that the granitic axis of the San Francisco range of the Coast Mountains *is newer than this sandstone.* The same is probably true of the other ranges. If, therefore, this sandstone formation proves to be Tertiary, as I am forced to believe from all the evidence I can obtain, we must assign a post-Tertiary age to the Coast Mountains, at least in the region of San Francisco.

The connection and apparent synchronism indicated between the rocks of the coal formation of Puget Sound and those of San Francisco, both by the similarity of mineral character and the universal presence of patches of lignite, is highly interesting, and worthy of note; leading, as it does, to the conclusion that valuable beds of Tertiary coal may yet be found in the Coast Mountains near San Francisco, or where the formation is developed.

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5. Remarks upon the Geology of California, from Observations in Connection with the United States Surveys and Explorations for a Railroad Route to the Pacific. By William P. Blake, of Washington.

(*Abstract.*)

Before the surveys of Lieutenant Williamson, in 1853, the topography and direction of the mountains between Walker's Pass and the Gulf of California were but little known. The surveys have shown that the lower portion of the Sierra Nevada, south of Walker's Pass, curves southwesterly, and unites with the Coast Mountains at the head of the Tulare Valley. The ridges in that latitude (35°) are not snowy, their elevation being less than 7,000 feet. South of this point of junction of the Sierra Nevada and the Coast Mountains a chain of high ridges is prolonged, and trends nearly east and west. It extends eastward from the Sierra Nevada to Mount San Bernardino, and forms the southern boundary of the Great Basin. This chain appears to be prolonged in the same east and west direction to the coast at Point Conception and Arguila, being in fact a *transverse chain* nearly at right angles

with the direction of the Coast Mountains and the Sierra Nevada. This chain extends from Point Conception to San Bernardino, and I have proposed for it the appellation *Bernardino Sierra.*

At San Bernardino the trend of the mountains again changes, and becomes more nearly north and south. At the base of the peak of San Bernardino is the wide and low pass of the same name (also called San Gorgonio), which, so far as is known, is the best pass in the whole chain south of the Columbia River. From this pass southwardly, there is a continuous chain of high ridges to the end of the peninsula at Cape St. Lucas. For this chain I have proposed the name of *Peninsula Sierra.* It forms in its northern part the watershed and barrier between the Pacific and the Colorado Desert, and between San Diego and the mouth of the Gila River. It has an average elevation in its northern part of about 6,000 feet.

The rocks of all these chains are chiefly granite, gneiss, and mica slate, including beds of white limestone and quartz rock. It was generally found that the central or higher parts of the Sierra Nevada were of compact granite; but even this was not free from a structural arrangement of the minerals. At the Tejon Pass, the rock was found to be filled with lenticular beds of hornblende, or hornblende and mica, trending in the same direction with the more highly laminated portions, or the mica slate. On the eastern slope of this pass, thick beds of white limestone, containing graphite, were observed, together with quartz rock, which are considered as indicating a sedimentary origin.

In the Bernardino Sierra, the granitic series is somewhat different; the rock is whiter, and contains a greater amount of feldspar or albite. The slaty or laminated form of granite is however found, and talcose slates bearing gold were seen. Several intruded ridges of porphyry were also found in this range. The eastern side of the northern part of the Peninsula Sierra consists chiefly of gneiss and mica slate; the rock of the western side is more compact, and is covered with soil and verdure, while the other side is bare and barren.

None of the palæozoic or older stratified rocks were seen during the survey; — they are either absent or have been metamorphosed. The only stratified formations are those of the Tertiary age, and the more recent deposits. The Tertiary strata flank the granitic elevations described, and rest horizontally upon the upturned edges of the slates.

The principal point where Tertiary strata are developed and characterized by fossils, is at Posé Creek, near the Tejon Pass. They consist chiefly of volcanic sands and pumice-stone, with argillaceous and sandy beds. The latter contains numerous fossils, among which species of the genera *Pecten*, *Natica*, and *Meretrix* are abundant. They are considered by Mr. Conrad as of the Miocene division of the Tertiary. Numerous sharks' teeth were also obtained from this formation, at an elevation of near 1,700 feet above the sea. Tertiary fossils were also obtained at the Cañada de las Uvas, San Fernando, San Diego, and at the margin of the Colorado Desert, along the banks of Carrizo Creek. Those obtained at the Cañada de las Uvas are from the Eocene division of the Tertiary, being well characterized by the well-known fossil shell *Cardita planicosta.*

The alluvial formations of California cover a broad area. The Sacramento and San Joaquin rivers form extended interior deltas, and the Tulare lakes are bordered by wide plains of barren clay, evidently of lacustrine origin. The immediate borders of the lakes are covered with a thick growth of gigantic bulrushes (*tulé*), and the shores being shelving, and the lakes shallow, they become much expanded during the rainy season, when the streams from the mountains are much swollen. King's River and the Ca-wee-ya are large streams, and form broad deltas covered with timber where they enter the lakes. The great valley or low plain of the Colorado Desert, lying far to the south of the Tulare Valley, and extending northwards from the head of the Gulf of California, is also of alluvial or lacustrine origin, and consists of a deep blue clay, which forms a hard, level surface. This clay is charged with small fresh-water shells, and they are found abundantly on the surface. This clay was proved to be of lacustrine origin by the existence of a distinct beach-line at the base of the hills, marking the former level of a sheet of water. This beach-line was distinctly developed, and could be seen on the other side of the valley, ten or fifteen miles distant. On the high ridges that extended out from the main chain into the valley a distinct water-line was found, and a calcareous incrustation two feet thick on the rocks, it having been deposited by the water. The evidences of the former existence of a vast interior lake were here seen on all sides, and in some places accumulations of boulders and pebbles were found strewed upon the surface, and so incrusted that it was evident they had not been disturbed since they were covered by the water.

I offer the following as the best explanation of the formation and subsequent desiccation of this lake. The Gulf of California probably extended to the head of the valley, 170 miles north of its present limits. The silt of the Colorado was probably deposited across this former extension of the Gulf, so as finally to shut off the upper portion, and leave it as a lake. The water has probably been evaporated by the dry winds of that desert region. There is reason to consider that the bottom of this ancient lake, now dry, is below the level of the Gulf; a great depression being indicated by the barometrical observations, and shown more conclusively by the fact that the waters of the Colorado, at times of freshets, overflow and run back into the Desert for many miles.

Further observations on the alluvial formations and the sands of the Desert were given, and remarks made upon the rocks of the coast near San Francisco.

The remarks of Mr. Blake were illustrated by a colored map, and at the conclusion a series of observations and remarks were made by Professors Agassiz, Guyot, Hall, and Dana, and by Dr. Le Conte and Mr. Leslie.

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## 6. Description of several Sections measured across the Sandstone and Trap of Connecticut River Valley in Massachusetts. By Professor Edward Hitchcock, of Amherst.

Three sections were exhibited: one crossing in the latitude of Turner's Falls; another in that of Mount Tom; and a third in that of Chicopee. A geological map of the line of the section, with the strike of the strata and the localities of footmarks, accompanied each. The strike and dip, as well as the distances, were obtained by the usual instruments; the heights by the aneroid barometer. Other sections are yet to be measured; but those exhibited lead to some important conclusions.

1. The hypozoic rocks, which terminate two of the sections, (the ends of the other being granite,) have a large dip towards the axis of the valley.

2. The trap ranges, crossed somewhat west of the middle of the

sections, form beds between the sandstone strata, and seem to have produced but little disturbance in the sandstone.

3. The strike of the sandstone varies from N. and S. to N. E. and S. W.,—in some places even to E. and W.; but the usual strike is N. from 20° to 30° E. The dip is almost universally E. and S. E., from 5° to 50°.

4. The sandstone, lithologically considered, exhibits three distinct varieties:—1. The rock lying west of or below the trap ranges is almost universally a thick-bedded coarse sandstone, passing into a conglomerate; the pebbles being granite, mica slate, and quartz. In the vicinity of the trap the color is often gray, and sometimes white. 2. A group of micaceous sandstones and shales of various colors, with thicker beds of deep-red and rather fine-grained sandstone. These lie immediately upon the trap, or to the east of it. 3. A very coarse gray conglomerate, the fragments often several feet in diameter, consisting of granite, gneiss, and micaceous and argillaceous slates. This deposit, which has been swept away, except a few isolated hills, lies the highest in the series, and towards its lower part is interstratified with the shales and micaceous sandstones, as in Mount Mettawampe.

5. With a single exception, the fossil footmarks occur in the second of the above groups of the formation, and chiefly near its lower part, where it rests on the trap. In a single case only they have been found immediately beneath the trap (on Holyoke). The fossil fishes all occur just above the trap; but the *Clathropteris* immediately below it (on Tom). With these two exceptions, nothing organic but fucoids has been found in the lower group,—the thick-bedded sandstone,—unless it be some fragments of dicotyledonous trees.

6. The sandstone has been raised since its deposition; for in some places (Turner's Falls), the most delicate footmarks occur on strata having a dip of over 40°; and the idea of animals walking on mud lying at such an inclination is absurd.

7. The perpendicular thickness of the sandstone on the different sections is as follows, estimated trigonometrically from the measurements in the usual way:—

| | Feet. |
|---|---|
| 1st section across Turner's Falls, . . . . | 14,124 |
| 2d do. across Mount Tom, . . . . | 12,241 |
| 3d do through Chicopee, . . . . . | 13,596 |
| Mean, . . . . | 13,320 |

Suppose we allow one half of this for original deposition, we have still left a thickness of over 6,000 feet. If there are faults, I have no certain evidence of their existence.

8. The discovery of the Clathropteris by my son, Edward Hitchcock, Jr., M. D., beneath the trap of Mount Tom, makes it very probable that the zone of rock in which it occurs belongs either to the upper part of the Trias, or the lower part of the Lias, where alone this fern is found in Europe. This would make all the rocks above the trap newer than the Trias, probably. Below this zone we have thickness abundant, according to my measurements, not only for the Trias, but also for the Permian, and perhaps still lower formations. And it is my opinion that the three groups of strata above pointed out are distinct enough in character and organic remains, to be regarded as separate formations. The two groups above the trap are thick enough, not only for the Jurassic series, but for the Cretaceous also.

9. The trap rocks were not the agency by which the sandstone of this valley was tilted up. For the dip is as great, and usually greater, beneath than above the trap. This latter rock was probably an overflow upon the bed of the ocean in which the sandstone was deposited; as the volcanic grit, lying above the compact trap, certainly was.

10. The agency by which this sandstone was raised, was probably the falcating lateral force that ridged up the Apallachian range of mountains generally; since the strike has a general correspondence with the direction of that chain. That force may have been exerted at several periods, and this may have been one of the last. The high dip of the hypozoic rocks towards the axis of the valley, as shown on the sections, indicates an approach of the sides of the valley, which must have crowded up the layers of sandstone.

The author of this paper professed an intention to measure other sections across this valley in Massachusetts, and expressed a hope that the same might be done in Connecticut; which, if done, may modify some of the preceding conclusions.

7. Additional Facts respecting the Tracks of the Otozoum Moodii on the Liassic Sandstone of the Connecticut Valley. By Professor Edward Hitchcock, of Amherst.

Some slight resemblance between the phalangeal impressions of this animal and the foot of an embryo frog led the author of this paper some years ago to refer it to the Batrachian family. He presented two other facts to strengthen this analogy.

1. The foot was possessed of a web, extending even beyond the toes. The specimens show this distinctly, especially some recently discovered; and it must have buoyed up the animal on the mud, like huge snow-shoes. Yet it sunk quite deep, and was, therefore, very heavy.

2. The toes were not terminated by claws, but by knobs. In this respect they correspond to many species of Batrachians.

At least two new localities of this extraordinary track have been lately discovered: one at Turner's Falls in Gill, and the other at the quarries in Portland, Ct.

The Otozoum was doubtless one of the most extraordinary animals that ever trod the earth. With a foot twenty inches long, and covering more than a square foot of surface, it must have been of gigantic size; and though apparently of Batrachian type, a biped Batrachian of such dimensions must have had great peculiarities of structure. The new *Ichnological Museum* of Amherst College, erected by the liberality of the trustees of the late Samuel Appleton, will contain numerous specimens of these tracks, for the study of future naturalists.

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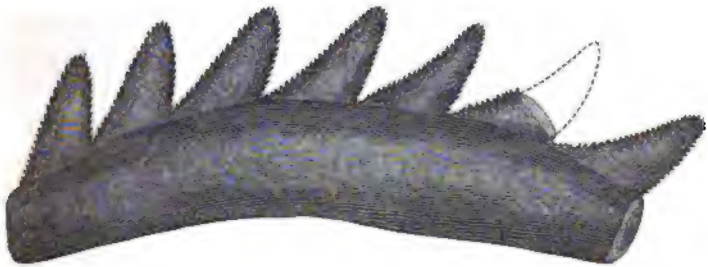
8. Traces of Ancient Glaciers in New England. By Professor Edward Hitchcock.

9. Inferences from facts respecting the Erosions of the Earth's Surface, especially by Rivers. By Professor Edward Hitchcock.

As these two papers require numerous drawings, to be made intelligible, and will probably erelong be published in another form, the author has judged it inexpedient to give even an outline of their contents in this place.

10. Account of the Discovery of the Fossil Jaw of an Extinct Family of Sharks, from the Coal Formation. By Professor Edward Hitchcock, of Amherst.



This beautiful and remarkable specimen was sent to the author of this paper by Rev. John Hawks, of Montezuma, in Indiana. It was given to him, to be sent to Professor Hitchcock, by Dr. S. B. Bushnell, of the same place. Mr. Hawks says: "It was found in Park County, Indiana, near the Wabash River, in a layer of slate, about one foot beneath the surface of the ground. Immediately beneath the layer of slate, which was about one foot in thickness, was a *coal bank.*"

Dr. Hitchcock stated that this specimen was evidently the jaw of a shark, but of very peculiar character. But it would be presumption in him to venture to throw out any suggestions concerning it, when we had one present to whom all the wonders of ichthyology, both recent and fossil, were as household words. He therefore called on Professor Agassiz to give his views respecting the specimen.

Professor Agassiz gave it as his decided opinion, that this specimen formed a part of the jaw of a shark, allied to the saw-fish, or Pristis family. He stated that the sword of the Pristis is originally composed of two bones, and if these should continue separated, each part, with teeth on only one side, would not be much unlike the fossil specimen. This is curved, however, and the teeth have fine serratures. He supposed that the fish had a corresponding jaw projecting from the opposite side of its head, and that both formed a powerful weapon of offence. He regarded it not only as an undescribed genus, but belonging to a new family of fishes; and spoke of the discovery as of

great importance in fossil ichthyology; scarcely inferior to that of the Ichthyosaurus and Plesiosaurus in fossil herpetology.

The author of the paper will commit the specimen to Professor Agassiz to be described. An accurate outline is appended to this historical sketch. (See figure.)

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## IV. BOTANY.

### 1. Note upon a Peculiarity of the "Redwood" (Genus Sequoia). By William P. Blake, of Washington.

The redwood, which is now used so largely for construction in the city of San Francisco, has the peculiarity of turning black, like ebony, when treated with an alkali. If a panel of this wood be prepared with a smooth surface, and then washed with a moderately dilute solution of caustic potash, the light red color — like that of our ordinary pencil cedar — is immediately changed to black, and the grain of the wood is beautifully developed. The carbonates of potash and soda produce the same result, but not so rapidly; it may also be accomplished by lime-water or ammonia. The effect is produced with most ease when the wood is freshly cut or sawn, and the pores are filled with the undried juices. A decoction of the wood is turned black in a similar manner; and I suggest that it may be used advantageously in chemical analysis as a test for alkalies. It would probably make very good test-paper, and tho reaction would be more evident and striking than with turmeric. When the alkaline solution is weak, the color produced on the wood is not a deep black, but has a shade of red, and resembles old dark mahogany, or rosewood. From the ease and cheapness with which the effect may be produced on the wood, and the extreme beauty of the panels thus prepared, it will doubtless become common to stain cabinet furniture and doors in this manner, in preference to painting.

2. NOTES UPON THE GROVE OF "MAMMOTH TREES" IN CALAVERAS COUNTY, CALIFORNIA. By WILLIAM P. BLAKE, of Washington.

THE grove of the mammoth trees is near the sources of the Calaveras River, in a depression between the hills, about 15 miles from the mining village called Murphy's. This little valley is said to be but 15 miles from the snow-line of the high ridges of the Sierra, and 30 to 35 miles from the crest. Its elevation above the sea has been approximately determined by the engineer of the Union Water Company, who considers it as 4,550 feet, and as 2,400 feet above Murphy's Camp.

The valley is densely wooded with evergreen trees, principally pines and spruces, and in some portions there is a thick undergrowth, which covers the ground from view. The great trees tower above this forest, — itself gigantic, — and present a magnificent spectacle when viewed from the surrounding hills. Mr. Lapham, who has erected a hotel in the grove, states that he has counted about 190 trees, including young and old. I saw about 20 of large size, and several young ones. They are irregularly distributed over a space a quarter of a mile square, and are generally in groups of two or three together. The principal trees have received fanciful names, such as *Father of the Forest*, *Beauty of the Forest*, *Three Sisters*, *Mammoth*, &c. Their size is variable, the diameters ranging from 15 feet to over 30, and the heights from 250 to 360 feet. The stump of the only tree that has been cut has been smoothed down, and made perfectly level, and now forms the floor of a ball-room. The solid wood of this stump, exclusive of the bark, measures 25 feet in diameter, and, with the bark, is about 30 feet. This is about 4 feet from the ground, where its diameter is probably 32 feet. The largest tree now standing, called the Mammoth, is of about the same size, but is imperfect on one side, a portion having been burnt out. I measured this tree carefully with a tape, and found it 94 feet in circumference at the roots, giving a diameter of over 31 feet. Although I did not measure the heights of these trees, I saw no reason to question the accuracy of the statements that have been made regarding them, and I believe them to range from 300 to 360 feet. One is said to be 363 feet, and an old one, lying prostrate, and much decayed, appears to have been

over 400 feet high. This prostrate tree is hollow, and I walked through it erect for a long distance; and it is said that, before the lower part became filled up by earth and stones, brought in by a brook, a man could ride through on horseback.

The tree which was cut down was partly used for lumber, and a part of the top has been levelled off, and a full-length double bowling-alley built on it. The log tapers so gradually, and its great diameter is so well preserved for a long distance, that at the extreme end of the alley it is not possible to get from the ground to the top of the log without climbing up by the limbs. This tree could not be felled by the ordinary method, and boring was resorted to, a long pump-augur being used for the purpose. The bark was stripped off from the lower part of the log, and sent away for exhibition. Since that time a second tree has been stripped of its bark to the height of 90 feet, and the tree is still standing. It is the intention of the proprietors of the grove to surround it with a spiral staircase, so that visitors may ascend to the top, and have a full view of the surrounding forest, with here and there a giant trunk rising above it.

The geology of the valley appears to be very simple. A hard, compact, gray granite was seen in the vicinity of the trees; it appears to be the underlying rock, and the soil is composed of its *débris*. A well has been dug at the house of Mr. Lapham, and the material removed shows that the soil is deep, and contains considerable fine white clay. Some rounded blocks of basaltic or trappean rocks are found on the surrounding hills.

The temperature of the valley is said to be mild, even in winter, the ground rarely freezing; but the snow generally lies 30 inches deep from January 1st until April. At the time of my visit (the first week in August, 1854) strawberries were just ripening, and columbines were in bloom. The heat of the sun's rays was very great at midday, but the shade of the forest was cool and delightful. The nights were also very cool.

The valley is abundantly watered; in the spring it is quite wet, and a good-sized brook flows through it.

3. Letter addressed to Dr. John Torrey, on the Ammobroma Sonoræ. By Mr. A. B. Gray. (Communicated to the Association by Dr. Torrey.)

New York, October 20th, 1854.

Dear Sir: — It affords me much pleasure to comply with your request, respecting the particulars of the plant now in your possession, which I discovered near the head of the Gulf of California, on my recent reconnoissance through the Mexican State of Sonora.

I had reached an Indian rancho, called "Sonoita," situated about fifty miles from the Gulf coast, and being desirous of extending my barometric observations to the level of the sea, as also to fix the latitude and note the character of the country in the vicinity of (what is called) "Adair Bay," it became necessary to obtain a guide. After much consideration on his part, and many Indian presents given him, I persuaded the "Governador," or head chief, of the Papijos of that region, to agree to conduct me to the sea-shore, and to this bay. On the third day of my travel (Wednesday, 17th May, 1854), under the guidance of the old chief, and after passing over an immense bed of basalt and volcanic lava, we came to a range of numberless sand-hills, extending southeasterly and northwesterly. These hills were of loose shifting sand, of about thirty feet summit-elevation above the surrounding plain, and about five miles broad. In a southwest direction they seemed to terminate at six miles' distance, but to the northwest they appeared to extend as far as could be seen with the telescope.

Immediately upon entering these sand-hills, our course being across them in a westerly direction, I observed the Indian dismount from his horse, and commence digging with his hands. At first I could not perceive his object, but shortly discovered that he had pulled out of the sand a vegetable-looking substance, which was shaped somewhat like a mushroom. He showed great eagerness to obtain more, and made a sign that it was good to eat.

Upon examination, I found this plant had a sort of pestle-shape, with a stem extending perpendicularly below the surface for several feet, and a round top of about two inches in diameter, partly protruding above the sand, say an eighth of an inch, the body or stem of the

plant about three quarters of an inch in diameter near the top, and two feet below somewhat larger; this part was not so brittle as the stalk of the mushroom, but more of the tenacity of asparagus, with a light orange-colored tinge on the outside, and the inside of a dull whitish color.

I noticed in pulling it up that it would snap off, and in but few instances did we secure any of its roots. It appeared to be either attached to something else, or to have a deep underground growth. The longest that I saw was about three and a half feet, but this was not the entire length, as it was broken off in pulling up. The top or head part was of a spongy substance, with small blue and purple pistils. The Indian gathered a bundle of them, breaking off and casting away the top of each. We encamped for the night in the sand-hills, and the chief, instead of supping with us, as usual, made a fire, and roasted his roots or plants on the hot coals (which took about twenty minutes), and commenced eating them. None of the party seemed inclined to taste, but, out of curiosity, I moved over to the chief's fire, and he handed me one. At first I ate but little, and slowly, but in a few minutes, so luscious was it that I forgot my own mess, and ate heartily of it; next morning each of the party "followed suit," and afterwards there was scarcely enough gathered to satisfy us. The taste, though peculiar, was not unlike the sweet potatoe, but more delicate. When first taken from the ground, and before cooking, it tasted more like the raw ground artichoke. The day following we noticed wigwams, and traces of Indians, which the chief made a sign to us were old encampments of tribes who lived at the Gulf shore, and who had been to the sand-hills to gather this vegetable. At noon we came upon a body of Indians encamped upon a ridge of sand, who, upon seeing us approach, made every preparation for a hostile meeting. Our chief, however, after a couple of hours' talk with them, induced kindlier feelings, when they brought back their women and children, who had been sent to a distance on our first appearance. We shortly after encamped, when they brought us dried fish, and a sort of *pinole*. The Mexican pinole is made of parched wheat, or corn, ground upon a *metat* (or stone), but of an entirely different color and taste from that of these Indians. They made signs that it was the dried vegetable ground into meal, and mixed with wheat. I ate of this pinole, and found it very nutricious.

The plant, when dried, or allowed to remain in the air a few days, becomes hard and dark, with an odor approaching to the Vanilla bean. In this state it becomes one of the principal articles of food with the tribes we met at the Gulf, they chewing it, as well as grinding it for pinole. They also get fish and crabs, which we found in abundance on the coast. They have nets, and I observed they had a great many *hawks* domesticated, but could not learn what use they made of them. The growth of vegetation in the vicinity of the sand-hills was chiefly stinted mesquit, cacti, iron-wood (called so by the Mexicans), and salt and hard cane grasses. The "iron-wood" bore a purple-colored pea-shaped blossom, was in full bloom at the time, a thorny shrub, and without leaves.

My party had just accomplished a journey and exploration of 1,700 miles, a great part of the way without roads or trails, and had undergone many privations and hardships, without guides, other than the instruments I carried along, and the knowledge I procured of a portion of the route from a previous reconnoissance and survey from El Paso to San Diego in California. They were on very short rations, and our animals from hard service weak and giving out, and with two long and dreary deserts to cross before reaching the settlements. Still, after approaching so near the point I had desired to reach when I set out, I was determined to hazard much to accomplish it. Everything had to be done by signs, not being able among the Indians to find one that spoke Spanish, and we, of course, not understanding the Cocopa or Papego languages. On returning from the head of the Gulf, we ate of this vegetable for about four days in its fresh and dried state, and found no bad effects from it. The Indians made signs that we were the first white people that had ever been there. We noticed this peculiarity among them, that, although a lazy set of Indians, they were well made, and fat, but had very bad teeth, even from the youngest to the oldest.

The latitude of these sand-hills is 31° 45′, longitude 113° 40′, and about six miles from the Gulf shore. No rain had fallen there for six months, it being the dry season. I regret I could not procure many more particulars relative to this plant, which interested me much from the circumstances attending the finding it; but should you desire any further information that I possess, which might aid you in discovering what it is, I shall be happy to com-

municate it. Similar sand-hills I noticed a hundred miles off, near the junction of the Gila and Colorado, but none of the plant was found in them.

With great respect, I remain very truly yours,

A. B. Gray.

Note. — This interesting plant will be described in full, and a figure of it given, in Mr. Gray's forthcoming Report of his explorations. It is evidently a new genus, nearly allied to the little known and anomalous Corallophyllum of Kunth, and the Pholisma of Nuttall. In the floral structure of scales it is more like the latter, from which it is distinguished by its woolly-plumose calyx, and its singular cyathiform inflorescence. The three genera may well be grouped into a small family, under the name of Corallophyllaceæ, or rather Lennoaceæ, as Lennoa is the older name of the typical genus. Lindley referred these plants to Monotropaceæ, in which he was nearer right than Nuttall, who placed Pholisma in Scrophulariaceæ.

John Torrey.

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## V. PHYSIOLOGY.

### 1. Laws of Reproduction, considered with Particular Reference to the Intermarriage of First-Cousins. By Rev. Charles Brooks, of Medford, Mass.

Whether the intermarriage of near blood relations is accordant with, or opposed to, the laws of nature, is a question which should be confined primarily to physiological science. Believing it to be important that scientific men should examine it, I take the liberty of inviting to it the attention of the Association, any of whose naturalists are better able than I am to discuss it; and some of whom could so examine and so decide as to put the question at rest. The improvement and prosperity of thousands of families depend on its solution; and, in a degree, the safety and elevation of society.

It is my purpose only to indicate *the course of inquiry*, and not to draw conclusions. When the facts shall have been collected and arranged, then the fixed and benignant laws which underlie the great

agencies of reproduction will be evolved. It is only by wide and thorough surveys that any reliable statements can be reached.

In examining the children of first-cousins, the temperaments of the parents must be specially considered; for it is thought that, where the temperaments are alike, the consequences are sure to be peculiarly disastrous; but where they are directly opposite, such consequences will not so appear. These results so much depend on temperaments, that they should always be classified accordingly.

Another circumstance to be regarded in these investigations is, the antecedents of the parents. Have any of their ancestors married first-cousins? and, if so, when did such marriages exist, and what were the health, pursuits, and character of the parties?

Other circumstances should be noted; such as climate, situation, and food. The effects may vary somewhat in high and low latitudes, in eminently civilized and eminently barbarous communities; and also where the marrying parties have indulged, through their youth, in great varieties of food; or where, as on small islands, and in the deep forests, they have been restricted to a fixed routine of meagre dishes.

Taking these and other related circumstances into view, we may begin to classify the facts thus:—

First. Those children, born of first-cousins, who are well developed in body, and vigorous in mind.

Second. Those feeble or peculiar in body only.

Third. Those feeble or peculiar in mind only.

Fourth. Those feeble or peculiar in body and mind.

The only way of settling the question is to take the census of a State. Take, for example, all the parents in Massachusetts who have married first-cousins; if a larger number of their children are found to die early, or to want a full development of body or mind, than the children of the same number of parents who have not married first-cousins, this will show that first-cousins should not marry together. Take one thousand couples who have married first-cousins; if more of the children of these parents are found to be imbecile, or defective in body or mind, than the children of *any* one thousand couples in the State found in similar conditions of life, this will prove that the marriage of such cousins is unwise. Again, if out of one thousand couples who have married first-cousins, there be particular families who have two, three, or even four children that seem weak or strange,

then this fact would be a strong presumption against the expediency of marriage between such near blood relations. Nothing but a true census can furnish adequate elements for a just calculation. Suppose one hundred thousand married couples in Massachusetts, and that five thousand of them have married first-cousins. Then suppose that there are six thousand children, among all who have been born from them, who appear different from the rest. They are either weakly in body, or peculiar in mind, and seem strange to their neighbors; some perhaps were born blind, some deaf; some with too many fingers and toes, and some with too few; some without hair, and some with too much; some talking in a strange way, and dressing in a stranger; some abhorring society, and some abhorring solitude. Suppose these six thousand persons are acknowledged to be different from the rest of mankind. Now, if more of them are children of first-cousins than the proportion which five thousand bear to one hundred thousand, then it is plain that the marriage of first-cousins is productive of disastrous consequences. To state the same fact in a shorter form: if one hundred thousand couples have six thousand imbecile or peculiar children, then five thousand couples should have three hundred of them, as their proportion. If by an *adequate* census it shall appear that the five thousand couples who married first-cousins have from three hundred and fifty to four hundred imbecile or peculiar children, then it will be proved that the marriage of first-cousins is forbidden of God.

It would be a lasting glory to any scientific philanthropist who should collect and arrange all the facts existing in any State of this Union. The field of inquiry is narrowed by certain facts. The Roman Catholic Church, by positive statute, forbids the intermarriage of first-cousins. England condemns it; and the people there have some strong and harsh sayings concerning it. The Quakers forbid such marriages; and some Cantons of Switzerland have forbidden them by law. Tradition, in this country, brings down to us two or three sayings on this subject, which most emphatically condemn such alliances.

I would now state a few representative facts, merely to indicate the course of inquiry. I shall confine myself to cases of children, born of first-cousins, who appear to be in a partly abnormal state of body or mind. There seems to have been in them an arrest of normal development; they lack that entire and symmetrical unfolding or equilibrium of the physical, intellectual, and moral powers which constitute a *whole* man.

For obvious reasons I shall give only the initials of proper names, and also of towns.

I. Instances of children, born of first-cousins, who lack normal development of *body*.

A physician writes me thus: "I have been a practising physician for more than fifty years, and I have not the least doubt that a large portion of the hereditary diseases which afflict certain families are derived from the intermarriages of close relations; for I have noticed that some families are predisposed to some particular disease; and where families intermarry with those of the same temperament, the strength of that predisposition is doubled."

Mr. C. H., of N., Mass., a shrewd and healthy man, married his first-cousin, an intelligent and healthy woman. They lost three children in infancy; and they have four now living, no one of them bright.

Doctor C., of N. M., New Hampshire, married his first-cousin, Miss B., of U., Mass. They had only two children, and both of them died in infancy.

Mr. J. P., of W., married his first-cousin. Both were in good health, and had active minds. Two sons died before the age of twenty-five; one daughter has diseased eyes; one boy is club-footed; one son died an idiot; and one daughter, who was like common children, married, and at the birth of her first child she died.

Rev. Mr. B., Episcopal clergyman of B., N. Y., married his own cousin; they had two children, both of whom died young.

A gentleman of W., M. County, New York, married his first-cousin. Both these parents were strong and healthy. They had several children, all bright-minded, but each one was a cripple.

N. and S. W., of T., are brothers. One married his first-cousin. Their children are blear-eyed, and feeble in mind. The other married a woman not related to him. Their children are stout, healthy, and bright.

In Adams, Jefferson Co., New York, there are two idiots, born of first-cousins. The head of the eldest, twenty years old, measures but nineteen inches; the other only seventeen inches.

A lady furnishes the following: "Mr. B., of W., married his first-cousin; had two children, both deaf and dumb. Mr. L., of W., married his first-cousin; had two children, both blind. Mr. D., of C. E., married his own cousin; had three children, all hermaphrodites."

In Virginia, where blood relations have intermarried much, in order to keep the property in the family, there are striking illustrations. One statement from a gentleman of Fredericksburg will suffice as a specimen. He says: "A certain family of wealth and respectability have intermarried for many generations, until there cannot be found in three or four of them a sound man or woman. One has sore eyes, another scrofula, a third is idiotic, a fourth blind, a fifth bandy-legged, a sixth with a head about as large as a turnip, with not one out of the number exempt from physical or mental defects. Yet they persevere in intermarrying, although these monuments are constantly before them."

Mr. P., of W., Mass., a fine-looking man, with strong health and good intellect, married his first-cousin, a lady of sound constitution and bright mind. One of their children was club-footed, another was idiotic, another sick and irritable, another near-sighted, another blind, and the rest feeble. Shall we say that these effects are only accidental, where there are such parents?

S. L., of A., married his first-cousin, Miss S. A. They had eight sons and two daughters. Two sons and one daughter are unable to walk. The youngest child is deaf and dumb.

On islands, small and far removed from the mainland, they are apt to marry in and in. A physician from such an island writes me thus: "On the southeast extremity of the island of C. there existed a small settlement of people, who, in consequence of a sharp quarrel with the main island, kept separated from it. The consequence was that they married in and in, till they had nearly all become blood relations; and by degrees they wasted in intellect, and became extinct. Their physiognomy was thin, and with some peculiarities of form. Two were born totally destitute of eyeballs. Their heads were very large, with an abundance of hair that covered their foreheads almost down to the eyebrows. On another island there is a family, the parents are first-cousins. There are four children, three sons and one daughter. The oldest son, who died recently, aged forty, had a peculiar organization: head very large, with hair growing over his forehead, and down his neck; eyes very large, and so constantly rolling that he could not fix his gaze for two seconds upon any object. He could not articulate, his tongue being too large. He had five fingers on each hand, and six toes on each foot. He knew enough to load and draw a hand-cart, and was exceedingly penurious. The second son is no

way peculiar. The third son is an incomprehensible being, with an organization somewhat like his eldest brother. He has all kinds of sense, except common; talks much and strangely, and in walking takes immensely long steps. The only daughter partakes of the influence. She has prayed the most of her time during the last ten years. In O. there is a family, parents first-cousins; they had thirteen children, and all, except one, died young. No one lived over twenty years, except the one yet living, who resembles a corpse. On another part of the island is a family, of whom the parents are *not* first-cousins; but they are closely connected by blood, through a chain of intermarriages reaching back several generations. "Within the last ten years," says the physician, "I have delivered the mother of four full-grown boys; three of whom were entirely destitute of eyeballs, although they had very deep sockets for eyes. Their heads were very large, and deformed on the front and top; one exceedingly so. Two of them died immediately after birth, and the other lived but a few hours."

II. Having adduced these facts, as specimens of the many I have gathered, it will not be necessary to add to them a large number which show an absence of normal development in the *intellectual faculties*.

Mr. E. S. and wife, of N., Mass., are first-cousins, both of sound mind and robust health. They had seven daughters and one son. Three daughters are deranged, and the rest are nervous.

Mr. T. A. married his cousin. They had five daughters, some of whom were far from brilliant, and two of them were cripples.

Mr. N. G., from D., New Hampshire, counted twenty-five families within his knowledge where cousins had intermarried, and he says that "not one of their children is above mediocrity."

Dr. H. W. says: "I know four brothers who married cousins, and each has a fool in his family."

Judge C., of H., New York, married his cousin. Out of several children, three were idiots. One only is living, and he has good sound sense.

Mr. E., of M., Mass., married his first-cousin. They have five daughters and three sons. One daughter is an idiot, and two are feeble-minded. One son has run away with the town's money.

A lady from Illinois stated to me the following facts: — "Two brothers married two sisters, and I knew them. The husbands were

not blood-relations of their wives. The parties were healthy and intelligent. These families lived near together on a retired country farm, and had few neighbors. There were many children, and all of them had usual health and common understanding. These children intermarried, and the offspring from these first-cousins were very different from their parents or grandparents. Several of the children died young. Of those who survived, some were idiotic, some talked most wildly, and dressed most strangely, and several were irresistibly bent on thieving. There did not seem to be a perfectly normal development among them."

I apprehend that such disastrous consequences as the above could result only where the temperaments of the parents and grandparents were alike. It seems difficult to conceive of such results as merely accidental, and not the effects of fixed laws.

"Mr. and Mrs. E., of M., Mass., had two boys. Everybody called them *dreadful odd*. Their minds seemed topsy-turvy, and they dressed differently from other folks."

Rev. Mr. Wisnor, of Boston, asked a friend: "Do you know Mr. C., who attends my church; he looks queerly, but he thinks more queerly still?" His parents were cousins.

Dr. Pinkney, of Key West, says: "I have seen many inhabitants of the Bahama Islands, the product of the many intermarriages there of blood-relations, and they were generally homely and short-witted." The Doctor further says: "I knew a family in P., New York, twelve miles from G., where the parents were first cousins; they had ten children, all of whom were idiotic."

The "skipper" who took me out on a fishing excursion had a son fourteen years old, who looked and acted as the children of first-cousins are apt to. I asked the skipper if he was married. He said: "Yes; this is my son. I have had many children, but have been very unfortunate with them all." I said no more; but on returning to my lodgings I asked the physician about my skipper's family. He said: "He married his first-cousin, and their grandparents were first-cousins. Most of their children died in infancy, and two of them were born with closed eyes."

There is a man in Massachusetts who married his brother's daughter! They had seven children, all idiots. The greatest age attained by any one of them was eleven years. So devoid of self-care were they, that

no one of them could feed itself. They would lie and roll on the floor, and appeared to be only masses of moving flesh. Are not such facts some proof of the violation of natural laws?

I know the family of E. E., of H., Mass. The parents are first-cousins. They have seven children; three of their daughters and one of their sons are idiotic.

Dr. Spurzheim, in the last lecture he delivered in Boston, made this remark: "Among the royal families of Europe who have married in and in, there is now scarcely one of their descendants who can write a page of consecutive sound sense on any scientific, literary, or moral topic."

Dr. Samuel G. Howe, Director of the Boston Institution for the Blind, has devoted his acute and benevolent mind to the investigation of the causes of blindness, idiocy, &c. He communicated a statement to the Senate of Massachusetts in 1848, Doc. No. 51. The following brief abstract is by my friend, Dr. Ed. Jarvis, of Dorchester, Mass., the author of the best American elementary treatise on physiology.

"The parentage of 359 idiots was ascertained. Seventeen were children of parents known to be near blood-relations. Three were from parents who were called cousins. One twentieth of all the idiots examined were offspring of blood-relations. The intermarriages of cousins do not constitute one twentieth of all the marriages, probably not one five-hundredth; therefore the marriage of blood-relations produces more than its share of idiots. All sorts of human deficiencies follow such marriages in similar ratio; namely, deafness, blindness, insanity, rheumatism, excitability, &c. Of the seventeen families where the parents were near blood-relations, most of the parents were intemperate or scrofulous. In some cases, both conditions prevailed. There were born among them 95 children, 44 of whom were idiots; 12 others were scrofulous and puny; one was deaf, and one was a dwarf. In a few instances all the children were either idiotic or scrofulous or puny. In one family of eight children, five were idiotic. Of the seventeen families the account stands thus:—

| | | |
|---|---|---|
| 6 have 1 idiotic child each, | . . . . | 1 × 6 = 6 |
| 2 " 2 " " " | . . . . | 2 × 2 = 4 |
| 3 " 3 " " " | . . . . | 3 × 3 = 9 |
| 5 " 4 " " " | . . . . | 5 × 4 = 20 |
| 1 " 5 " " " | . . . . | 1 × 5 = 5 |
| | | 44 |

Nearly one half ($\frac{44}{95}$) of their children are imbecile. Add those otherwise imperfect, the 12 scrofulous and puny, the one deaf, and the one a dwarf, then we have 58 in all; thus showing more than one half ($\frac{58}{95}$) in an abnormal condition. The parents who had the four idiots had also four other children who were deformed."

An aged physician sends me the following statement: "A family in the town of B., Maine, named S****, is as follows: the parents have good constitutions, and the usual intelligence; they are first-cousins, and have five children. The first child is healthy in body, and regular in mind; but the other four are miserable idiots. They are disgusting objects to look at, their tongues very large, lolling out of their mouths, and saliva constantly flowing; eyes staring in the most stupid manner; and when they are alone will pick up worms and eat them."

Charles A., of Little Compton, R. I., shot his cousin, Valentine A., August, 1855, when his cousin was leaving Charles's house, after a friendly visit. Charles's father married his own sister's daughter, and the murderer was the product of this marriage.

In Rhode Island two brothers married nearly at the same time. One married a lady who had no blood relation to her husband; the other married his first-cousin. All the parties had good health, and a common share of intellect. Each couple had three children. The children of the couple who were not related were healthy and intelligent; the children of the first-cousins were all idiots. At the birth of the third idiot, its mother died. Two years afterwards the widower married a lady who was not related to him. They have two boys, each is athletic in body, and very bright in mind.

It is not necessary to my purpose to extend these heart-sickening details of human calamity, mortification, and disappointment. With all of them fresh before us, are we authorized to draw conclusions? I think not. It is the part of sound philosophy to suspend decisions until both sides can be fully examined. There are children born of first-cousins who possess full vigor of body, and commanding strength of mind. All such cases are to be carefully registered, and profoundly studied. There are also children born of parents who are not related, who are weak in body or imbecile in mind. These have their place as elements in the present investigation.

With the facts now stated, and others which have come to my knowledge, I would ask the following questions: —

First. Are not the laws (used or misused) which improve or deteriorate the breeds in lower animals, the very same laws of nature which improve or deteriorate the human race?

Second. Are there not found, in the same family, an unusual number of imbecile children, who are born of parents that are first-cousins?

Third. Do any children, born of first-cousins, exceed their parents in bodily strength and beauty, or in mental activity and power?

In closing, let me hope that the Association will not allow the subject to rest till the true conclusions are reached. If members will make note of facts within their knowledge, and forward them to me, I shall feel greatly obliged.

This subject includes an examination of the great fact of *caste* throughout the world. It includes an examination of the South Sea Islanders; of poor Africa, which has suffered through ages from the terrible class-castes, which keep them separated into hostile fragments, thus compelling intermarriages with the same tribe. It includes our American Indians, and may explain in part their diminution in numbers and bravery. It includes the Jews and the Gypsies.

I can assure the student that all these branches will be found full of deepest interest. When the great laws of amalgamation are properly understood, it will not be difficult to show the world how Mr. Knight, of England, has introduced the "Durham short-horned" variety of cattle; or his race-horse, that will leap eighteen feet; or his draught-horse, that walks off with two tons on a level road. It will not be difficult to explain the thick lip introduced into the imperial house of Austria, by the marriage of the Emperor Maximilian with Mary of Burgundy, although it is three hundred years since the event. It will not be difficult to explain the unusual strength and stature of the females of Potsdam, where the King of Prussia had quartered for half a century a guard of gigantic soldiers. It will not be difficult to explain the surpassing beauty of the Circassians and Georgians; or the short stature and small limbs of those parts of Ireland where the true Celtic blood is unmixed; or the stronger and larger limbs of other parts of that country where they have intermarried with English settlers and the Lowlanders of Scotland. It will not be difficult to explain the superior physical and mental qualities of the mixed races in Paraguay, in contrast with their neighbors; or of the offspring of the Dutch in their union with Hottentots. Baron Humboldt says: "It is a

well-known fact that the Samboes of S. America (the progeny of blacks and Indians) are remarkable for their physical superiority over their progenitors of either side."

Let the student be assured that all the branches of this wide subject will open before him fields for sublime contemplation and increasing wonder; and when he has exhausted them in other countries, he may then turn to the most interesting and extended exhibition of them all, namely, the United States; and he may try to calculate what will be the solution of the great problem here. Will not our country furnish the most wonderful example of the effects of intermarriages with different castes of the Caucasian race? When the people of these United States become a mixture of English, Scotch, Irish, Germans, and French, will they exhibit a strength of body and an intelligence of mind, a true inborn energy and moral power, which do not equally signalize either of the nations from whom they sprang? Under the fostering care of a truly republican and Christian government, will they advance in science, arts, agriculture, commerce, manufactures, and all the blessings of a religious civilization and political equality, as no one of their parent nations has? Let us hope that it is the appointed destiny of our free and prosperous land, to exhibit a higher development of human attributes than has yet blessed or astonished mankind.

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## 2. On the Sterility of many of the Varieties of the Domestic Fowl, and of Hybrid Races generally. By Dr. Samuel Kneeland, Jr., of Boston.

The mania which has of late years manifested itself for unnatural crosses in quadrupeds and birds might, if scientifically investigated, lead to many interesting facts bearing upon hybridity. I refer, of course, to *bona fide* crossings of allied and remote species.

A few years since, most naturalists believed that our varieties of domesticated stock, as of cattle, sheep, goats, dogs, fowls, &c., were derived, each genus respectively, from a single wild original; and that man's care had obtained from this the numerous existing varieties. In the present state of our knowledge, we think we are justified in saying that the varieties above alluded to have been produced by

the crossing, natural or forced, of several more or less nearly allied species. For instance, who shall dare to decide between the Asiatic buffalo, the European aurochs, and Cuvier's extinct ox, as the undoubted wild original of the varieties of our cattle? Whence the necessity of reducing all varieties to a single stock, endowed with great powers of variation, especially when there are several wild species, each entitled to be considered the original? It would seem that the simplest view of the case is the best, namely, that these varieties are the result of the mingling of many species, guided by the wants or caprice of man. In short, I believe that no *one* wild original can lay claim to the origination of the varieties of our cattle, of our sheep, of our goats, of our dogs, of our barn-yard fowls; — and, to carry the opinion to the legitimate consequences, that no *one* species of MAN can lay claim to the paternity of all the *human* varieties. The reasons for this opinion have been often stated, and will not be repeated here; they may be found in the writings of Hamilton Smith, Morton, &c. Some new observations will only be added in confirmation. And yet, with this belief in the diversity of origin of our domestic animals and the human races, it seems to me that *hybridity* is a true *test* of *specific difference.* It is an axiom with some, that *different species* will not produce fertile offspring; and hence, to them, the fact of the production of such offspring proves that the parents belong to the same species. On the other hand, Dr. Morton makes different *degrees* of hybridity, the offspring being more prolific according to the nearness of the species; thus making hybridity *no test* of specific difference. Of these opposite opinions I prefer the first. By a hybrid race I do not understand an offspring prolific for a few generations, and then gradually dying out, or feebly supported by crossing with the original stocks, but a race capable of propagating itself without deterioration, without any assistance from either of the parent stocks. Such a race, I maintain, has never been seen, and never will be, under the present laws of animated nature. You may take any part of the animal scale, from a barn-yard monster to a mulatto, and the fact is the same, — they cannot hold their own; they must die out unless crossed by the pure originating blood, or must return to one or the other of the primitive stocks.

The subject which suggested these remarks is the sterility and deterioration of some of the highly-bred varieties of our domestic fowls.

It has become quite a source of complaint by many farmers, who in former times had plenty of eggs from a small number of common fowls, that, since the mania for rare breeds, they have been unable to obtain their usual supply of eggs and chickens from the same number of birds, and have been subjected to great annoyance and pecuniary loss. It is a natural consequence of forcing birds of different origins, and from different countries, to propagate a hybrid offspring, for this very reason prone to degeneration. The difficulty is increased by the impossibility of crossing the stock with the supposed originals. The size of the bird, in this as in other cases, seems to be obtained at the expense of the reproductive powers. The admixture of different species, and breeding "in and in," have been carried beyond the limits fixed by nature, and deterioration is the result.

The same thing occurs in the mulatto, and other hybrid human races. The mulatto is often triumphantly appealed to as a proof that hybrid races are prolific without end. Every physician who has seen much practice among mulattoes knows that, in the first place, they are far less prolific than the blacks or whites; — the statistics of New York State and City confirm this fact of daily observation; — and, in the second place, when they are prolific, the progeny is frail, diseased, short-lived, rarely arriving at robust manhood or maternity. Physicians need not be told of the comparatively enormous amount of scrofulous and deteriorated constitutions found among these hybrids.

The *Colonization Journal* furnishes some statistics in regard to the colored population of New York City, which are painfully interesting to philanthropists. The late census showed that, while all other classes of our population, in all parts of the country, were increasing at an enormous ratio, the colored were decreasing. In the State of New York, in 1840, there were 50,000; in 1850, only 47,000. In New York City, in 1840, there were 18,000; in 1850, only 17,000. According to the New York City Inspector's Report for the four months ending with October, 1853, —

1st. The whites present 2,230 marriages; the colored, 16.

2d. The whites present 6,780 births; the colored, 70.

3d. The whites present about 6,000 deaths (exclusive of 2,152 among 116,000 newly arrived immigrants and others unacclimated); the colored, 160.

Giving a ratio of deaths among acclimated whites to colored

persons of 37 to 1, while the births are 97 to 1. The ratio of whites to colored is as follows: — Marriages, 140 to 1; births, 97 to 1; deaths, 37 to 1.

According to the ratio of the population, the marriages among the whites during this time are three times greater than among the colored; the number of births among whites is twice as great; in deaths the colored exceed the whites, not only according to ratio of population, but show 165 deaths to 76 births, or 7 deaths to 3 births, more than two to one.

The same is true of Boston, as far as the census returns will enable us to judge. In Shattuck's census of 1845 it appears that in that year there were 146 less colored persons in Boston than in 1840, the total number being 1,842. From the same work the deaths are given for a period of 50 years, from 1725 to 1775, showing the mortality among the colored to have been twice that among the whites; of late years Boston probably does not differ from itself in former times, nor from New York at present.

In the Compendium of the U. S. Census for 1850 (p. 64), it is said that the "declining ratio of the increase of the free colored in every section is notable. In New England the increase is now almost nothing"; in the Southwest and the South the increase is much reduced; it is only in the Northwest that there is any increase, "indicating a large emigration to that quarter."

What must become of the colored population, at this rate, in a few years? And what are the causes of this decay? They do not disregard the laws of social and physical well-being any more than, if they do as much as, the whites. Prominent among the causes of decay is the continual attempt to mix races, — the hybrids cease to be prolific; the race must die out as mulatto; it must either keep black unmixed, or become deteriorated, and finally extinct. Nobody doubts that a mixed offspring may be produced by intermarriage of different races. The Griquas, the Papuas, the Cafusos of Brazil, so elaborately enumerated by Prichard, show this; the question is, whether they would be perpetuated if strictly confined to intermarriages among themselves. From the facts in regard to mulattoes, we say unquestionably not. The same is true, as far as has been observed, of the mixture of the white and red races in Mexico, and Central and South America. The well-known infrequency of mixed offspring between

the European and Australian races led the colonial government to official inquiries; and to the result, that in 31 districts, numbering 15,000 inhabitants, the half-breeds did not exceed 200, though the connection of the two races was very intimate.

A recent opportunity of witnessing the landing of a large colored picnic party afforded the most striking proof of the inferiority and tendency to disease in the mulatto race, even with the assistance of the pure blood of the black and white races. Here were both sexes, — all ages, from the infant in arms to the aged, — and all hues, from the darkest black to a color approaching white. There was no *old mulatto*, though there were several *old negroes*, and many fine-looking mulattoes of both sexes, evidently the first offspring from the pure races. Then came the youths and children, removed one generation farther from the original stocks, and here could be read the sad truth at a glance; — while the little blacks were agile and healthy-looking, the little mulattoes, youths and young ladies, were sickly, feeble, thin, with frightful scars and skin diseases, and *scrofula* stamped on every feature and every visible part of the body. Here was hybridity of human races, under the most favorable circumstances of worldly condition and social position; and yet it would have been difficult, and, I believe, impossible, to have *selected*, from the abodes of crime and poverty, more diseased and debilitated individuals than were presented by this *accidental* assemblage of the victims of a broken law of nature.

Such facts as these lead to the belief that hybridity is a true test of specific difference; and that admixture of species, in man or animals, must end, sooner or later, in deterioration and extinction, — very soon if unmixed with the pure stocks, and later if thus mixed; that, at any rate, extinction is the doom of the hybrid race, either by absorption into the parent races, or by slow decay.

For wise purposes, which we can know but imperfectly, the Creator permits, as we see, different races of men and animals to produce fertile offspring *inter se*. Thus far, and no farther, can man go in his attempts to mingle species, which change perceptibly within narrow limits, and then perish, or return to their origins.

One of the consequences of this opinion is, that the *genus* HOMO consists of several *species*.

3. Contributions to the Physiology of Sight. By Dr. T. C. Hilgard, of Philadelphia.

## I. *Accuracy of Sight and Means of Accommodation.*

In both these subjects important points are still enveloped in doubt, partly from a want of explanation, partly from indistinct or equivocal conceptions; but chiefly from a want of sufficient experiments, and the effect of others which, by equivocal results, have produced only more obscurity. It may, therefore, not appear superfluous to introduce some original observations and experiments tending to elucidate those points in a connected exposition of the whole subject, in order to show their bearing, and to bring a number of known facts under their proper point of view, without, however, any pretensions to novelty.

The simple considerations must necessarily precede the compound, — the consideration of monocular that of binocular vision.

However far an eye can reach, it is impressed distinctly only with a single distance at a time, all objects more remote or near appearing for the moment ill-defined or vague, while they may be rendered distinct in their turn, to the disadvantage of others. This adjustment is known to be subject to volition. The eye is supposed to adapt itself to suit given distances, which faculty is called that of *accommodation.* The range between the farthest and the nearest distances of well-defined vision is the *scope of sight.* In near-sighted (*short*-sighted) eyes it embraces only a few feet. In normal and far-sighted ones it can extend to celestial distances. The two eyes differ mostly in this respect: the short-sighted one may, for example, see accurately from four inches to six feet distance, the normal one from three inches to infinity.

To see parts as *minutely* as possible, we must bring them as near as possible, the angles then being the largest. Experiments, however, seemed to show that *perfect accuracy* of sight took place at a distance different from that, and that it also had a certain *scope*, in near-sighted eyes, nearly coinciding with that "of vision" generally.*

The limits both of visual range and of *perfect accuracy* (not a very

* In normal and far-sighted ones, however, "exceedingly variable, even extending as far as 500 feet." (Budge.)

good distinction, as the latter seems to be included in the very definition of the former) are determined by *optometers*, which are graduated bars, with a sliding test-object, to be stopped where it begins to be indistinct. Thus, for establishing the scope of *well-defined* vision, the point of an acute corner is used in an object plainly visible as to size, the point being produced by the meeting of two rectilinear margins. It is set up at a distance, where it has as good definition as the eye is capable of. It is moved toward the eye by degrees, affording the organ a little rest at each station; suddenly a point is arrived at where the points and margins become *diffused* by a spreading dimness. Thus, a *nearest* and a *farthest* limit are obtained, if an infinite distance too can be called a limit. For the determination of the extent of minute vision *print* is generally chosen, which is moved to and fro so far as possible without becoming *inconvenient to read*, — a circumstance greatly dependent on external circumstances, such as illumination, and chiefly *size*.

It is evident that, in seeing with both eyes at once (binocular vision), when it is required that both eyes be *accommodated to the same distance*, and that their axes *meet* at that distance, the impressions of both eyes being then duly superincumbent in our consciousness, the range of defined as well as minute vision cannot extend beyond the nearest one of the outer limits of the single eyes, nor this side of the farthest inner limits, that is, *cannot extend beyond where the eyes can operate in common.*

It is also evident, that, in experiments on visual accuracy, all artificial inconveniences, and chiefly all *exclusion and diffusion of light*, as far as not founded within the organ itself, must be carefully avoided. This fundamental requisite, however, we find entirely disregarded by most optometrical contrivances, by being complicated with the *Scheiner* experiment. The eye is constructed after the plan of a camera obscura, and accuracy of sight obtained by focality of the *retina*, the nervous expanse in the rear of the camera and lining the eyeball. The idea is to make supervening extra-focality more perceptible by preclusion of the more central rays, thus causing an incipient or total separation of retinal images, as soon as homocentric rays are no more unitable on it. A screen is placed close to the eyes, with two stitches or clefts in front of the pupil, but so as to have its centre screened, and only a few lateral pencils of light admitted, each producing a dim

configuration of its own representing the lucid object, — as in an occultation of the sun, when its orb is left crescent-shaped, each chink in the foliage will project on the ground a crescent-shaped luminosity, while a full sun projects round specks, and a candle shining through pin-holes as many inverted representations of itself as there are chinks. These, if collected by a lens, will form a single image in its focus, but forward and backward of it as many separate ones, gradually seceding as they recede from the focus.

Nothing so quickly affects the eye morbidly, and causes rapid destruction of nervous eyesight, as *diffused rays*, such as are caused by the proximity of a screen's surface, in the first place. In the second place, this contrivance, in precluding the central rays, precludes the only rays that can be united into an exact focus, owing to the spheric form of the lens; thus in no case can an exact image be obtained, even if focal. Thirdly, the intensity of the light normally admitted through the pupil is reduced perhaps to its hundredth part, the pencil of incident light being thus reduced. Fourthly, the inflection of light passing by margins, or through chinks (condensation of air along surfaces?), causing a considerable aberration, will never permit of an exact image being produced.

Hence, the complication with the *Scheiner* experiment not only leads to incorrect results as to scope, but furnishes a multiplicity of results that belong to quite a different class of optic phenomena.

In experiments on *scope*, as well as *minuteness*, the objects must be perfectly *open to sight*, and duly illuminated.

In experiments under conditions entirely plain and natural, the moment the sliding point in contemplation passes the limits of accommodation, that very moment it becomes *ill defined*, clearly enough so to be at once observable. If brought *near the proximal limit*, that indistinctness can be contemplated as such, and studied in its form and nature *with paramount attention*, without producing the slightest change, except that the *ideas* concerning it flow more freely. Nor does the *wish* to see more clearly for itself produce any sensuous change. It is only an *exertion of will to that purpose*, — an *exertion*, not a mere wish, and a very sensible exertion, — that is able here to produce accommodation. This exertion is clearly felt as a *muscular one*, and occupying the whole orbit except the middle filled with the eyeball, thus *exactly corresponding to the position of the external eye-muscles.*

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In accommodation for distance, on the contrary, the greatest feasible *relaxation* is experienced. If the *muscles* with which we turn and move the eyes be wilfully relaxed to the feasible extreme, not only the eye-axes assume a parallel position, as in *adaptation for infinite distance*, but at the same time each eye is *accommodated* for infinity. If the muscles that move the ball be wilfully "strained," contracted as much as possible on all sides, then the eye is found to be in accommodation for greatest proximity.

These experiments are accessible to every one, and can be realized without an apparatus. I think it a most important support for the theory, that *all sensuous exactness*, also in the eye, *is produced objectively, and as far as voluntary by muscular action.*

Besides certain universal, mostly unconscious, but often voluntary, irradiating effects from person to person, and strictly dependent on and expressive of *psychic* conditions, the notorious manifestation of the mind on the material world is *muscular action*, namely, by a *material exertion of will.* A mechanical effect of the mind is thus produced, but also a *sensuous* one, producing a voluntary correctness or indistinctness of perceptions. In the four lower senses these effects, too, have been proved to be *mechanical* ones, *owing to muscular action*, by rendering the form of the ultimate sensuous *stimulus* more defined. The exertion of will to *hear* more distinctly affects the *musculus tensor tympani* to span the tympanum, whereby better-defined vibrations are produced, that come to a final perception accordingly. The *olfactory* perceptions are regulated by the modes of inhalation and mastication (see Proceedings of 1854, p. 251), the *gustative* by the latter; while the recognition of qualitative diversity among the impressions once perceived is a subjective function much dependent on *attention.* In sensuousness we have two psychic functions: a passively sensuous one, *perception*, and an active intellectual one, *recognition* or judgment, which, being of the intellectual order, is affected by attention.

We have, therefore, every reason to expect that distinctness of vision, too, is owing to *physical* conditions, in the first place, and secondly, as it is influenced by exertions of will, to *muscular* action.

It was evident that distinctness of vision depended on distinct representations on the retina; at least this idea was not to be left, and recourse taken to inherent psychic faculties, before all possibilities of a physical nature were properly explored (*exploitées*) and exhausted.

We must here make a few remarks on the proper method of physiological investigation, as by a want of it physiologists were so frequently misled to skip their best and due chances of a proper understanding, running their boats directly ahead into the shoals, instead of following the *channel*, floundering upon *instabilis tellus*, *innabilis unda*, when they attributed distinctness of sensation to *attention*.

All sciences consist of two parts: *the empirical mass and matter of facts*, and the *understanding* thereof, or knowledge of relations ("the humor of it," — Shakespeare). In natural sciences this is self-evident, as the empirical mass is so much more ponderous than the ideas concerning it. Even in mathematics, if no objective casualties had led to various researches of relations (as each one of unknown magnitudes requires an independent equation or concrete occurrence), its system would never have been generated. Its present form is an accidental one. It is not complete. Who can tell how to complete it? No science was originated *a priori*, but *a posteriori*, starting from concretes or casualties.

The empirical is the body scientific; the understanding, the soul thereof. The empirical is the reality to operate upon. Understanding is the comprehension of the unknown by the known. We must in each case proceed from the *most known*, *most real*, *most absolute*, — this is, no doubt, the fundamental rule. The second is to skip no link of the chain, and to linger at each until all combinations are exhausted.

For us there are two different, though corresponding, realities or empiricisms. But few connecting links are known. One is *sensuous* empiricism, which brings the impressible but blank mind to the knowledge of a reality not founded within itself, the "outward world"; the other is the *mental* empiricism, which takes cognizance of its own inherent conceptiveness and energies, its intellectual and moral processes and results, to which sensuous empiricism furnishes the material to digest.

As the becoming conscious in our sensuous energies depends entirely on *material casualties*, these are to be considered as the conditioning causes, the *empirical domain* or reality of sensuosity, and therefore we must, in the explanation of sensuous phenomena, *commence* at the most extraneous, as the most conditioning in the concrete cases; but in the determination of the intellectual, and its effects on

the physical world, at our *mental* consciousness, each in its turn being the most primal or fundamental.

A real explanation requires to be constituted of facts and *pre-established* conceptions; otherwise it is no understanding of unknown by *known* things. If not so, they only appear as hypothetical postulates, each hypothesis remaining to be proved.

Thus is it with the assumption of *attention* as a factor in *sensuous* phenomena. *Attention* we meet on the empirical field of *intellect*, not of *physics*. It is in the *intellectual* range that we fall in with it, that we experience and conceive of it. Here it is that its properties must be studied. If the properties thus established can explain anything in the sensuous way, so much the better. If the study of each conception, sensuous and intellectual, be commenced at its *proper source*, if at all conductible so far as to meet, they are sure to *meet at the right point*. In what relation attention stands to the sensuous, namely, indirectly by steadying the conceived will, we shall presently see.

From the proper manifestations of attention, I think it cannot be more plainly qualified than as *the faculty of the mind to persist in a direction once assumed*. It is, as it were, *the momentum of the mind*, the *persistence of animadversion*.

Wherever the mind is *fixed* upon, thereunto the ensuing thoughts *e*volve and *re*volve. This power of attention in intellectual matters being so well known, the temptation was great to ascribe to it a similar efficiency and productiveness in sensuous phenomena. It exercises its influence on will and judgment, but not on sensation itself. The explanation of sensuous accuracy by attention must therefore be rejected, as, —

In the first place, satisfactory explanations can be furnished by *physical* causes dominating the final object of perception.

In the second place, attention has *no such power pre-established*, which would at least remain hypothetical; if not

Thirdly, the physical experiment *disproves* attention to be at all directly influential, except by actuating the *mind* to ideas and will-energy. We may hear sounds as distinct or as indistinct with equal attention, and distinctly or indistinctly without attention, the impression on the sensorium remaining the same. We may read with eyes or hear a whole page distinctly, without becoming conscious of the

*sense* conveyed, if attention be absent. Returning, it may cause the mind to peruse the last impressions meaninglessly impressed on the sensorium, the last words, the strokes of a clock. Sensuous recollection will repeat the words, the strokes, such as they were, and the now attentive mind may conceive of a meaning in the words, and of a number of the strokes, &c. Indistinct vision, as we have shown, can be "*attended to*," and conceived *as such* with perfect attention, without thereby becoming more distinct.

Physical distinctness was to be sought for. Being voluntary, it was to be sought in the organ. It was to be sought in its *stimulus*, light. Light presented distinctness in the focus. The focus was found on the retina. The retina was found sensuous to light.

Olbers computed a variability of 1‴ of distance between the lenticular system and the retina to answer all purposes of accommodation. Recent experiments have shown the difference of focus in (dead) human eyes, for objects from 4 inches to infinite distance, to be about 1‴.

What could produce this requisite volubility? The most fabulous and directly untrue explanations were given, facts asserted that do not exist, and credit given from "want of a better," or rather from mental laziness.

*Within* the eye, *in loco*, no original motive causes can be adduced. The *cornea* (the transparent outward convexity) does not change. Next comes a fluid. The lens changes its position *quite actively*, and in accommodation for proximity its surface has been observed to come forward.* There are no voluntary organs of motion within the bulb, only involuntary muscular fibres subservient to the reflex action of the *iris*. A circle of half-gelatinous muscular papillæ at its insertion and base (*corona cillaris*), projecting not more than at most $\frac{1}{16}$ of a line, was put in requisition to "press the lens backward," in order to produce accommodation for distance, against the united stress of four powerful lengthwise muscles; the "*straight*" ones, fixed at the very recess of the orbit, and spanning their flattened sinews over the globosity of the elastic ball, ending near the cornea; and two transverse ones, forming a tractile *belt*.

The most plausible, and probably the only possible explanation,

* The writer is at present engaged in a series of experiments on that subject with *obscured lenses* and *pupillar adhesions* in living eyes.

was for a long time quite neglected. The bulk of the ball, between the retina and the lens, which it bears in front suspended in a strong transparent diaphragm, is occupied by a toughly gelatinous elastic mass (*corpus vitreum*). A pressure of muscles acting always on it around its "equator," it *cannot help yielding* to their various degrees of tension, as the bulb cannot move backward, being sustained in position by a fatty bolster behind and laterally. It must yield in the free direction, must *elongate*; hence it *cannot help to produce various accommodations*, elongation being required for accommodation to proximity. Relaxation must shorten the intra-ocular distance, *does* accommodate for distance. The *corpus vitreum* being elastic, it must yield in the axial direction in both senses; if the retina be swelled backward ½‴, elongating the bulb ½‴, the lens may also be moved forward ½‴, and the total difference is 1‴, as required.

The accuracy and delicacy of changes is obviously explained by the disposition of the forces, a great contraction of a muscle producing only a small lateral effect on the bulb over which it is bent.

We have stated before, that all *exertion* to effect accommodation is felt to be a muscular one in the locality of these outward or voluntary eye-muscles. Also, if those muscles be wilfully contracted, then the eye is really accommodated for proximity. Also, if we *rest* and *relax* the eyes, they not only assume the parallel direction, but are accommodated for distance. Every one can thus practise wilful accommodation.

I mention these facts in corroboration of this theory of accommodation, held and cultivated by Von Graefe (at Berlin). Whoever may have been the first to originate it, he proved it conclusively by the observation of the effects of morbid and artificial paralysis of the external eye-muscles, the latter ensuing directly on an application of the *neutral sulphate of atropia*, long before any of its effects on the iris and interior parts take place. The muscles being relaxed, the eye stands out and is accommodated for an inalterable distance, namely, farthest distance; — whatever be the wishes or "attention" of the patient, the organ to execute his will is paralyzed!

The conditions of the *distinctness or indistinctness* of sight, and the degree of accuracy, depend, —

1. On the fact that only the central part of the retina, situated where in looking straight forward the optic axis is incident, is organ-

ized to perceive *forms* distinctly. The eccentric parts are less delicate in form-perception. Images laterally incident are less distinct.

2. On the focality or extra-focality of the central part of the retina. That part being out of focus, it perceives distinctly the inaccuracy and diffusedness of the images. If, by a slight distortion of the bulb, as in *turned* eyes, it changes its position toward the optic axis, the intense light of that axis will be incident obliquely, and hence diffusedly, all points except one being out of focus, and produce a less distinct, but a far more fervent perception.

3. The gelatinous body (*corpus vitreum*) in a normal state offers no conditions, except that its refractive power, like that of all the refractive mediums, influences the distance of focus and correction of light-dispersion. Also, all morbid conditions of the several organs, infiltrations, exudations, hœmorrhages, &c., in short, all material lesions, interpositions of opaque bodies, morbid changes in the refractive powers, and the sensitiveness of the nerve, are influential, but are here not further entered upon, as being abnormal.

4. The irregularity in the lens, causing luminous points (stars, lanterns) to appear *beamed and pencilled*, &c., and resulting from the peculiar arrangement of the fibres around two amorphous Y-shaped central configurations, an upright one in front, and an inverted one behind, producing the appearance of a six-rayed star, — in the lens to the looker on, in the sky to the looker *out*. Of course the *size and intensity of these diffusions of light*, and their changes in deflected-looking, *constitute a minimum limit of accuracy*, outlines being diffused to a certain extent; hence figures whose retinal image is within the extent of that aberration will be no more distinguishable as to form. Thus objects of a size insufficient to subtend a certain visual angle are absorbed in the irradiation. In what relation this dispersion stands to the focus and its distance from the lens, hence to accommodation, has not yet been ascertained, to our knowledge. The unsteady accommodation of the short-sighted eye, that cannot adjust for parallel rays, in binocular contemplation of a star will produce a certain vacillating contingent of its apparent "*rays*," while other and most eccentric beams are superadded by the capillary attraction of moisture along the pinched or quivering eyelids.

5. The spheric form of the lens causes a spheric aberration, the rays passing through lateral parts not becoming united in a perfect

focus. This alone would produce a certain mellowness of outline, and hence a minimum limit of visual angle; but its effect is much smaller than that caused by the starry irradiation of the lens, resulting from its structure. If, however, the *pupil* be considerably enlarged, as in looking into the dark, the effect is very sensible, increasing the extent of the irradiation, and by falling on eccentric parts will cause great luminosity and fervency of color; hence,

6. The width of the pupil is of great importance. In the dark, and in accommodation for distance, it enlarges, admitting of a greater quantity of light. In the latter case, without any detriment to accuracy, spheric aberration being the less considerable, the less divergent the rays, the farther the object of vision. The yellow light uses and pains the eye the most, causing a stronger contraction of the pupil, and less admission of light generally. If by a screen, spectacles, or a chimney of true-blue (e. g. cobalt blue) glass, much of the yellow light be precluded, the expanded pupil admits of so much more light that the increase of quantity more than compensates the loss of certain rays, and vision is actually brighter through such glasses that are really somewhat darkening.

The *humor aqueus*, — the fluid between the lentine diaphragm and the *cornea*, — as well as the latter, does not in a normal state present any conditions for dimness of sight.

7. The lachrymal fluid streaming down over the eye, and the margin of the eyelids where it accumulates by capillary attraction, has been mentioned before.

8. The direction of the eye-axes in binocular vision. If they fail to meet (converge), as in muscular debility (Von Graefe) by overstraining, so frequent in seamstresses ("dulness of sight"), as well as for points before and behind the distance of converging axes, *double vision* exists. (Collateral correspondence of retinal parts, the right side being perceived as coincident or "identical" with the right, the left with the left side of the other ball, is obtained by rays from identical points at the distance of converging axes.)

9. The difference of accommodating power or scope of sight. A co-operative eye, unable to accommodate for the distance for which the other is adjusted, will receive only a diffused image, and trouble the clearness of the other. Hence distinct binocular vision cannot exceed the scope between the farthest one of the proximal and the nearest of

the remote limits afforded by a pair of eyes as above mentioned. In two eyes co-operating, every want of accuracy in one will injure the correctness attainable through the other singly.

10. All the outward conditions influencing the state of the arriving light, as aerial dispersion and vacillation. On alpine heights, through a serene and homogeneous atmosphere, thousands of feet above the dusky atmospheric ledge overspreading the lowlands, on snow-fields 40 miles distant, "small type" executed in letters of 1,500 feet would be read as easily as that of $\frac{1}{30}$ of an inch on a page at 8 inches' distance, which in its turn would cover towering summits, as that of the Toedi, seen near Zurich, in Switzerland, the angle being the same. Sizes increasing after the same ratio as light decreases in intensity, — namely, after the ratio of expanding angle or rectilinear emanation, — distance itself being without influence as to intensity, and as to aerial dispersion, the loss is perhaps more than compensated by the enlargement of the pupils.

*Ceteris paribus*, vision is minutest under conditions where angles become largest, namely, at the greatest proximity that can be accommodated for, and this is proved by experience. But that adjustment requiring a great exertion, and exercising the greatest pressure on internal parts, it can be sustained only for a very short time. The muscles become tremulous, tears flow, the eyes ache and become dark, &c. For a sustained minute vision a greater distance is chosen, some of the angular size being readily sacrificed to comfort, and a certain empirical distance for close work is habitually assumed.

We have thus for each single eye as to *accuracy*, —

1. *A scope of well-defined vision* equal throughout, provided the angles under comparison be the same, and allowance be made for external obstacles to light.

2. *A distance of minutest vision*, being the proximal limit of accurate vision generally.

3. *An habitual scope of minute vision*, much dependent on external conditions, and more distant than the proximal limit of accurate vision. To such very variable distances of comfortable minute-sight the images of unknown distances are referred, to reading-distance in a microscope, say 8 inches. The culminating sun and moon, if considered half a foot in diameter, as they mostly are, being $\frac{1}{2}°$ of angle, are put at about 60 feet height, the height of trees and houses; if considered 2

or 4 feet diameter, as the rising moon sometimes is, at about 120 or 240 feet, — distances from which we *scan* such buildings and houses. In a telescope, the moon, though magnified and more distinct, is sometimes imagined as the contingent part of the objective glass (the eye-piece being too near), or is set at the reading distance of common type. Astronomers are apt to assume no definite idea of telescopic size at all.

4. A *degree of acuteness* or accuracy, or a minimal angle, dependent on the aberrations within the organ.

In binocular vision allowance must be made for the peculiarity of each eye, and their co-operation, the effects of either being mutually superincumbent.

### II. *Visual Judgment of Position.*

We realize the existence of space by movement, made conscious by resistance in space, through touch. The sensation of muscular exertion is one of touch, namely, of a dull pressure in all the muscles employed; hence the more expanding and diminishing, the farther from the point of resistance. Thus we know of locality by touch, because perceptive of *resistance*.

Taste teaches nothing of locality, except by effects of pain or contraction (pungency, acridity, astringency, — see Proceedings, 1854, p. 249). The lingual sense, as well as the olfactory and auditory, teaches us nothing about space, only about specific sensations. It is only touch and pain, and the latter hardly otherwise than as far as determinable by touch combined with motion, that teach us about the localities of the other specific sensations. We think we taste everything in the mouth, where we have organs of touch and motion, while the greater part of it, the "*peculiar flavors*," are perceived at a few inches' distance above it, in the nasal organ. Olfaction, however, though essentially the same as flavor-tasting, we place pretty correctly, as we *feel* the streaming coolness of the air. Yet we place it about an inch too external, because the cool air and the fingers do not reach farther, and it is they (touch) that give us locality. Things taste "delightful to our palate"; while tasting we move the gustative tongue along the (hard) palate, which itself has neither a gustative nor an olfactory perceptiveness, but only that of touch or localization. We do not know where we *hear* the sounds. By motions (positions of the head) we ascertain from the greater or less intensity of sound whence it pro-

ceeds, but not where it is perceived. A soreness at the faucal entrance of the *eustachian tube* (connecting with the middle cavity of the ear), we place in the external ear, near the tympanum, just beyond what we can *reach* with the tip of the finger. Each organ has a tactitive apparatus: the tongue its lips and muscles, &c., the nose its tip and skin, the ear its conch and the flap thereof, — pretty sensitive are those appendages as lips and tips, real bolsters of taction, — and the eye has its lids, lips as it were, its very sensitive external surface, and its muscles, all three constituting a very delicate organ of touch, and hence of locality, harmonizing with all ideas of space acquired by the proper organs of localization, the extremities.

The internal parts of the eye have no tactitive sensitiveness. If the optic nerve be pinched, it answers by a flash as of lightning. The retina, if touched by the pressure of a finger on the ball, answers by a ring of light. It is a *local* effect. Still the perceived light is placed at several inches' *distance*. Therefore our visual ideas about position are only a function of *judgment*, an operation of the *mind*, not of the eye; and the mind refers it so as to harmonize with its acquired ideas of space as given by taction. Whereto the muscle must pull and the *conjunctive* (the sensitive external membrane of the eye-front) feels the lids gliding along, and whereto the fingers may grope both the object and the direction of the ball, thereunto is the contingent visual impression referred. How we would refer without taction is a vain question, for we *have* taction, and *know of space*.

In handbooks of physiology, even in monographs, we almost invariably meet a wonder expressed how it is that we "see things upright," whereas, the eye being constructed like a *camera obscura*, a reversed image is projected on the retina, — "and it is this picture we perceive." Here is the error. The idea of the *picture* consists of *two* things: of light-impressions and of relations of space (forms, &c.). To perceive light is the department of the visual nerve. This is what we *perceive* of the "picture." To conceive of *form* therein is the part of judgment by reference to space-consciousness, touch. We evidently do not perceive *that* picture at all, for we are in no way subjectively conscious even of the existence of our retina, much less of its size. We continue to feel even as the child does; our looks *travel* out, and glide over the surfaces we view, penetrate into distances, sweep, return, — all of which are ideas of *taction*, the more so as any

*exertion* towards the visual determination of distances — parallax — is felt as one of *touch* (muscularly). The exertion to accommodate to distances is the effect of the same muscles, and the turning in directions *per se*. The *co-occurrence* of certain *sensations of light* with certain *ideas of location* being infallible, and the real connection subjectively unknown, we imagine light-perception to be localizing or tactitive, referring two facts in causal connection directly together, just as any two points can be connected by a direct or straight line. It holds good until the moment where we affect the retina by touch: here we see an incongruity between vision and touch, one that, be it well remarked, does not alter in the least our ideas about the location of either the finger or the organ, but of the light-effect, — we place it outside. If we press the outside of the ball, the fiery ring will appear to be beyond the nose at four or five inches' distance, and coincident with a ring produced by pressure on the (correspondent) inside of the other eye, beyond the nose, placed at one or two inches' distance from its actual locality, at the very point where an object must be put to make light incident on these two corresponding parts, provided the nose would not interfere, which it does however, showing that, even where they cannot possibly co-operate, two retinas are made to "correspond," after the general plan. Each eye refers light where touch has taught us light *proceeds from*. If persisting awhile with closed eyes, one almost succeeds in bringing the two sensations in *direct* connection, localizing the ring unto the touch, but never referring the touch to the distance the ring seemed to hold.

That to the *retina* all references to space are only acquired and not absolute, is easily proved by the fact, that all these relations can be trained to their very reverse, while in no case a continued incongruity between our present and former spacial consciousness and actions (motions, &c.) takes place. Dressing before a mirror, we change our visual relations to motions; right becomes left, &c.; and if you comb your hair backward, it seems to go absolutely forward in the glass. Still the practice of reversing the relation is so soon acquired, that we do it unconsciously. On turning away from the instrument, whether glass, microscope, or telescope, we have only to reverse the practice of our eye-muscles in relation to the others, which makes the eye spin for a moment, and their instability causes vertigo, an incongruency between the tactive effects of gravitation and a customary

relation of one set of muscles to the others. Resistance caused by gravitation regulates our ideas about up and down, the only fixed starting-point of space we have. Thus the eye, as a whole, is not only a visual, but also a tactile organ, in this combination more delicately so than the rest, *localizing* the sensations of its *visual* apparatus. The *specific* sense of the eye is *luminosity*, but *sight is a co-operative function of two, as taste is of three senses.*

Blind-born persons acquire a most accurate tactile knowledge of space. On receiving eyesight, they immediately refer visual impressions as we do, and upside remains safely upside, because all light-impression is localized by application to touch.

That we have in our retina no actual or reversed knowledge of upside and downside is proved by standing on the head, thus reversing the retina, while our ideas about up and down remain exactly the same.

If we had any knowledge of *actual size on our retina*, its impressions would be in a perpetual conflict with actual sizes of *touch*, which is not the case. That we have not is also shown by the experiment of looking through a magnifying lens, and drawing with the other eye an outline to coincide with the magnified image; although *coincident*, hence equal in angle and retinal extent, still the sketch may seem three times larger, because three times nearer than the habitual distance assumed in the microscope. The two impressions are not recognized to be equal in size, although their "pictures on the retina" are, one factor of our judgment of size, tactile distance, being different.

Hence the only faculty we need assume for the retina is an empirical knowledge of the relative retinal subtensions of angles, or power of empirically identifying certain retinal distances (sizes) with certain differences of direction taught by touch. This would suppose that in the organ certain *directions* were in immediate relation, or, as it were, identification with certain *points of the retina.* This would require organs in immediate connection with the retina, each having a direction of its own, and by it a physical action on the part in question, so as to refer to it individually. It would require millions. *And so we find it:* the bottom of the transparent retina is paved with myriads, as it were, of parabolic mirrors of very minute size, their mouths toward the centre, their axes in radial positions. It is the deepest or most peripheric stratum of the retina itself, the so-called "cylindric bodies,"

conoid crystalline bodies severed from their darkly pigmented matrix by a coating of a yellowish oil, which constitutes the concave mirror. Some have claimed these crystalline elements as the seat of luminous sensitiveness.

Thus an identification of retinal parts with directions and their differences, angles, may be acquired. This done, sizes may be judged by the application of angles to tactile (feeling and convergent) distances, and, *vice versa*, distances by the angles of sizes tactually ascertained, which would seem sufficient to explain all the phenomena in question.

### III. *On Subjective Color-Effects, and their Relations.*

Every impression of light or color disposes the eye to produce the sensation of its complementary light and color as soon as withdrawn from the former influence. Gazing in the direction of a red surface suspended on a white wall, when the red sheet is dropped, a green configuration appears in its place. Yellow produces lilac or purple; blue, orange; and *vice versa*. The *phantom* or subjective complementary effect will endure some time, according to the strength of the impression. Dwelling on a colored surface, namely, perusing it in divers directions, the impressions along the margins will be alternately mixed with the adjoining colors, while the impression of the centre remains uniform, hence becomes most intensified by duration, and therefore will produce the most enduring complementary effect; hence the phantoms of a uniformly colored surface will commence vanishing by the margins, while the centre endures, and the waning phantom will present a rounded appearance.

Pink casting its light upon a face will improve the incarnation. As the cheeks slope downward, a pink neck-ribbon, e. g. of a bonnet, will answer the purpose. Let it not be too large, or too intense, or else the rest of the face will suffer by the contrast. Contrast is produced by the repeated superincumbency of the phantom or complement of the other. Green trimmings in the upper part of a small bonnet will cause a green reflection on the receding and shadowy parts on the head, hence produce a heightened pink in the front and lower part, by contrast. Green reflected on the incarnate skin will make it look whiter and marble-like: green may be reflected on the forehead, pink on the cheeks, from below. Bathing in the blue waters of a Swiss

lake makes the skin appear of a shining white, by absorption of the yellow rays in incarnation. A change of color may be produced either by addition of colored light, — by reflection of real, or by addition of subjective contrast-colors, — or by subtraction of certain rays by a colored screen.

Dwelling with the eye on surfaces, the effects and counter-effects are strongest in the centres; hanging on along margins, they heighten each other up to greater brilliancy, to the detriment of the centres, that appear obscured. The brilliancy and soulfulness of colors is chiefly the result of those magic hues dwelling within the vitality of the organ itself, in the living contemplation. Hence, in painting, the great object must be to direct the eye so as to cause the desired effect. The masterpieces of the master-painter, Raphael, have always been admired for these effects, aside from their other merits. If these effects were physiologically as well understood as they are intuitively appreciated, we should probably not see such very imperfect copies in either color or engraving. In his own portrait, in the Louvre, the extreme indistinctness of outlines is remarkable. It is like gazing at a face with two eyes and dilated pupil, without coaptating or accommodating the look of pathos and feeling; and the features become impressed only from dwelling on the whole at once, as it were joining regions to regions, and not lines to lines: thus the effects of color become those of heightened centres, instead of margins. No better study of this can be afforded than in his Madonna di Sisto, where the vision of the Virgin with the child is, by this delineation in tints and shades, put in a most effective contrast with the figures of reality at either side, Sixtus and St. Barbara. The beauty of the latter is comparatively soon conceived, as it were, by being drawn in distinct outlines, — the easy way-guides, — and ever exchanged for the absorbing contemplation of the visionary figures that "fetter" the gaze, no less by the diffusedness of design that causes the eager eye to infuse its own floating colors from part to part, from tint to tint, than by the sublimity of the conception. A similar effect of mellowness, to "absorb," without however affording that brilliancy of color, is perceptible in several Murillos. The subjective colors may be said to be waking dreams of the eye, — hence "entrancing."

It seems that the phantoms appear more perceptibly if projected on a background out of focus, and thus become more active at each

change of focus. If from an illuminated part the eye passes over a depth in the perspective, into which it does not enter, as in the recesses of a bouquet, or the like, the phantom of the last impression will hover over that extra-focal background, not only showing that extra-focality to exist, but also by contrast heightening the impression last received. Lively contrasts are indicative of proximity. Thus the hovering obtuse counter-blot serves to indicate perspective by a double agency: by relieving the foreground, and by indicating a change of depth; besides this, they serve artificially to correct the material imperfection of color in the material. These effects are largely used in painting, although quite empirically, in order to produce perspective against the consciousness of the flatness of canvas, continually realized by the coaptation of the triangulating eye-axes, and, like all such auxiliaries to artificial perspective, require to be somewhat exaggerated, or set down more forcibly than commonly found in nature. As these effects are entirely dependent on the succession, duration, and alternation of parts, they are expressive of the whole mode of contemplation of the artist, who, after having finished the details, will stand aside, obliquely scanning the whole, and, impressed with the effects as he subjectively perceives them, will set these *finishing-touches*, teaching the eye where to roam, where to rest, what parts to take as masses, what in detail, what *order* to follow, and where to centre. They are the expression of the genius, the power, and the whole individuality of the inventor. His work *speaks* to you, as you make anything in nature speak to you after your subjective fashion. The copyist and the feeble put no such touches, if not themselves impregnated with the same spirit. A natural flower speaks to you as a unit, as an entity. The most exact copy by a fair hand will remain a delicate and exact copy of what she has distinguished, but too frequently lacks the power of individuality, while a strongly characterized representation needs no very detailed execution. For the ultimate end of art is the psychic impression.

We would here speak of the effects of oblique vision, or "sheep's eyes" (German *schief*, = oblique). It is known how works in colors and extensive prospects are scanned "*askance*," i. e. with the eye-axes strongly deflected from the forward direction. It is chiefly done by inclining the head sideward, and not facing the object directly. A very remarkable *luminosity and softness* (fusion)

*of colors* is the immediate effect, while the details of form are also fused, hence less individualized and distinct. It has been frequently noted as taking place when looking through the spread legs. I have found it to take place invariably at *every deflection of the optic axis.* Looking through the legs toward the sky is deflecting the axis towards the infra-orbital margin. One-eyed persons will look at things and persons the same way, — it seems to increase the perception of light. Turning the eyes (not the head) upwards, produces the same effect, in each case not momentary, but enduring with the position, and in direct proportion more intense the greater the deflection. It can easily be tested by facing a sunset, with *the eyes fixed on it*, turning the head or the whole body around the vertical axis. The more you turn, the higher is the flush, that alternately fades down as you come to face that part directly forward. It also takes place in exercising a pressure on the front of the eyeball, and also when the pupil is dilated, as on suddenly awaking in the night, or emerging from a light room into darkness. Awaking, the eye is most sensitive, and the pencil of light admitted very great. Strong light also facilitates *sneezing*. Man and beast, if in distress for a sneeze, will squint as obliquely as possible at the strongest luminary available. By looking askance, a greater mass of light seems to become available on a sensitive part.

The stronger and more uniform the impression of a color, the less distinct the outlines, the stronger are the mutual effects of contrast. The effect on the landscape is really wonderful in an Alpine country, where on an eminence one overlooks all the landscapes and distances contained within say fifty miles, especially near sunset, where the coloredness of the light, and the diversity of its colors, add to the individualization of each part of the prospect by its proper illumination and atmospheric conditions. The orange glow of the setting sun will produce a "humid" twilight over the shadowy lake, and a "deep entrancing blue" on the craggy *silhouette* of the chain behind which it sinks, and on the bluish spruce-tree, through whose chinks it beams in all the splendor of one's own beams and splinters in the eye (lens). The haze of each separate distance will appear greenish, brownish, purplish, by a common fusion of its lights in the soft haze of its atmosphere, and by the aberration and fusion of rays within the deflected eye, the small objects being absorbed. No adaptation taking place, the whole prospect looks "as if painted," as if breathed into the

sky; also from a gentle feeling of vertigo resulting from the exertion of the eyes to keep the horizontal line.

What may be the cause of these phenomena? — dispensing awhile with "effect of imagination," "attention," and the like, as we have to do with sensuous phenomena, and not with thoughts and feelings, their centre and destination.

What is the common characteristic of the phenomena? Intensity of luminosity, and deficiency in ocular touch, form. The former must have its cause in a heightened light-effect, the latter in a change of form. Light-effects are heightened by an increased pencil of light, by increased contrast, and by greater nervous sensitiveness. The latter we must reserve for the last, being the least sensibly objective, the most psychic relation of sensation, and we must commence with the physical. The consideration of indistinctness of form is still more physical among the effects. But the most physical is the first physical cause. This consists in a change of positions. In dilatation of the pupil in the position of the iris. It admits more light, hence greater intensity in the focus, and, as to form, a greater dispersion and fusion, a part of it passing through lateral parts of the lens. In the other cases, the common characteristic is a change in *pressure*. Pressure itself (uniformly exercised) has no such effect, as in accommodation for proximity the luminosity is not greater, nor vision less defined. Whatever distances are out of focus appear with a fusion of color, without any particular heightening, as is naturally to be expected from the diffusion of rays, but on parts of the retina less sensitive, as lateral objects seem to appear less defined in form and color. The ball being elastic, pressure changes its form more or less. The eye turned aside, the muscle on that side exercises probably no compression at all (at most by its own increased thickness), its sinew being no more spanned over the convexity of the eyeball, while on the opposite side the pressure must be somewhat increased by the tension of the muscle, and its application on a greater arc. The result must be a slight distortion, in the rear, towards the contracted muscle. The transverse eye-muscles, being inserted tangentially, will have but little influence by their effort to preserve the horizontal line. Such a distortion will cause the optic centre of the retina to obtain *an oblique position*, and perhaps even the optic axis will turn a little aside of it. The optic axis being obliquely incident, only one point can be in focus,

all the rest extra-focal, intercepting the pencils more or less before or behind the focus. This will produce a *fusion of rays and forms.* The central intensity will sweep a greater number of elements, although each with a smaller pencil, and this may be a cause of the greater *intensity* of light, our given experience. Also the reflecting coating of the cylindric bodies, the minute conical mirrors, are struck laterally and one-sidedly instead of in their axes, and perhaps this might afford an explanation. The exact construction and the locality of sensation being as yet unknown, all being parts of the retina, this very fact of increased luminosity may lead to the determination of the sensitive locality, which must be sought at the point where in oblique incidence *more* light is collected, or where the *sums* of light-effects are increased *by obliquity.*

In reading, hence in typography, the dazzling or confusing effects of intersection by phantoms ought to be considered. *Parallel dull* ground-lines, of about equal *bulk* with the white, and somewhat *knobbed* at the end, are most suitable. All *oblique* lines, as in v, w, x, as well as *curved* and *tapering* lines, as in bowed letters, all *recurved* lines, and all fine bristles, ought to be avoided. The distinctive character of all letters ought to be at the same level, but easily to be recognized by means of their more bulky dependencies. Old English, and the small letters of German type, according to experience, are least affecting to irritable eyes, and eyes generally.

# C. PRACTICAL SCIENCE.

## ENGINEERING.

### 1. On the Use of Salt-Marsh Sods for facing the Steep Slopes of Parapets, Terraces, etc. By Lieutenant E. B. Hunt, U. S. Corps of Engineers.

Along our Northern seaboard, and especially on our New England coast, there are numerous and extensive salt marshes, which are overgrown with a very thick turf of marsh grass. They are usually alternately overflowed and left dry by the rising and falling tide. The grass with which they are covered is, so far as I have observed, chiefly of three varieties. The coarsest or sedgy grass is found in those parts which are most deeply covered by the tide-water, and is much less thickly set on the surface than the others. I am inclined to think that this may be but the eel-grass of deeper water, slightly changed by rising out of the water. The second variety is that commonly known as " fox marsh " grass, and is quite fine and thick, of a lightish green tint, and uniform in character. The third variety, known as " black marsh " grass, grows on land which is wet, but not usually flooded, and is of a much darker and richer shade of green than the others. Fox and black marsh hay is much used for packing ice, &c., for which it commands quite a remunerating price. The effect of draining is said to be, that the coarse grass is replaced by fox marsh, and this in turn by black marsh. The fox and black marsh are said to require rains for their healthy growth, and to be affected by droughts even when rooted in salt water.

If the turf of either of these three varieties be cut into, it will be found to consist almost entirely of a compact mass of fine roots, the roots of the coarse grass being larger and less tenacious. The color of the turf grows darker in descending, and the toughness, which is a maximum on the surface, decreases with the depth, until, at the depth of about two feet, the fibrous structure loses its predominance, and the material becomes mucky and deficient in strength. Below this it is a true peat, with more or less impurities, according to its locality. The

section is what might be anticipated from knowing that this peat is a gradual result from the decay of the lower roots, and that a surface growth of vegetation is the origin of the entire bed. The sod itself has a great degree of strength, elasticity, and durability. It is like a sponge in its absorption, and in its recovery of shape when compressed, if the roots are not broken. Taken on to dry land, it loses a large part of its weight, from the drying out of its water. In good localities, sods can, without difficulty, be got out as much as eighteen inches deep, and strong enough to bear pretty rough handling without injury. The roots are partly macerated at the first, but drying removes this, and adds greatly to their strength.

With the sanction of the Chief Engineer, I have during this season applied these sods for facing the breast-height slope of over 1,000 feet of battery crest at Fort Adams, Newport. Parapet breast-heights, or interior slopes, are generally built with masonry walls to within eighteen inches of the crest, and the remainder consists of a slope which it is desirable to have as steep as one base to three vertical. It has proved impossible to make any common grass sodding which would stand on these slopes, nor has any satisfactory construction yet been found for this case, unless it be by the use of salt-marsh sods. After careful observation, there seems to be every reason to hope that they will perfectly meet the demands of this construction. On Fort Adams alone there is an extent of over two miles of such crest, whence its importance is apparent.

These sods were used for building a parapet of a fort at Gloucester, Mass., during the war of 1812, and General Totten thus employed them in various instances at that time. On seeing the Gloucester parapet, in 1850, I was struck with its excellent preservation, and indeed I think it has lasted decidedly better than rough masonry would have done in its place. There is one great difference between this construction and that of Fort Adams. At Gloucester the sods are cut thin, and laid with their edges to the face; at Fort Adams the sods are from twelve to fifteen inches thick, and laid on their edges, with the grass facing outwards. I have been told that in Ireland field walls for fences are made by cutting these sods in small blocks, and laying them up, grass outwards, on each face, filling between the roots with bits of sod, and covering the whole with loam. The sods are cut from trenches along the wall, and the top of the wall is planted with vegetables. It

is found that the grass continues to grow on the sides, and the walls themselves are said to be very durable. The poor cottages with peat walls which prevail in some parts of Europe also illustrate this durability. The well-known antiseptic property of peat is evidently closely related to this durability of salt-marsh sods.

The mode in which work has proceeded in facing the Fort Adams breast-heights is this. The fox marsh sods are cut with a long hay-knife, by plank guides, into blocks eighteen inches square, and from twelve to fifteen inches deep. They are moved by hand-barrows, and are boated to the work. The breast-height wall, being cleared and its top plastered and asphalted with a heavy brush coat, is furnished with slope guides of six inches base to eighteen inches vertical. The precise angle to which each sod should be cut is measured by a bevel square, and applied on a side of the sod, which is then pared to the required bed by means of a long two-handled knife. It can be cut with great neatness, and, by successive trying and trimming, the joints are made nearly perfect for the entire depth. The sod is placed on its edge, and slightly projecting over the wall, as a roof to its exposed angle. It is then compressed by means of a lever and plank, so as to thoroughly close the joints, and to prevent any opening from drying. Having laid a line of sods in this manner, they are backed with earth, and covered with common sods, which by guttering the back, are doubled over to form a little over an inch of the face slope. Thus only grass is seen. It is already apparent that the marsh grass will continue to grow, and that the fox grass will become black grass. The construction has very great solidity, and can hardly fail to stand unimpaired for a long time. Its military qualities as a parapet cap, and for embrasure cheeks, are admirable, as it is free from stones, and cannot scatter fragments when struck by a ball.

As the availability of these sods for various constructions seems not to be much known, I have thought it might be of some general use to lay before the Association this notice of a strictly professional construction. It has seemed to me unquestionable that these sods could be in many instances advantageously used for facing *terrace slopes*, where the height is not great, and when a lack of space makes steep slopes desirable. Thousands of New England cottages which have or need terrace slopes are within striking distance of marsh sods. By laying two or three depths of sods on masonry principles, quite

high facings could be made, with slopes of one base to three vertical, on which a rich coating of black marsh grass would almost surely grow, if the sods were cut in the spring; or, if desired, the sods could be laid with the edges outward, making a brownish, regular wall. This application is one which I have never seen or heard of, but I am so confident of its advantages in many cases, that I do not hesitate to recommend its trial.

The species of sod-fence before described must, I imagine, be of great value in some localities where timber is costly, and it seems deserving of the attention of those interested. There is another application, which I have never heard of or seen, but which seems to me very promising. This is in the construction of blind drains. The walls, bottom, and top of a drain could, with much facility, be built of such marsh sods. The sod edges would form good drain walls, and they would doubtless suffice for some open drains. They would present the great advantage over stone of giving free passage for water through their masses. They could readily be cut so as to be used for stairs in terrace slopes, and elsewhere. They would also form a durable bordering for walks. By laying them grass downwards, and smoothing the root faces, they would make a footpath or sidewalk of great softness, elasticity, dryness, and permanence. A dike over a marsh at Newport, built of sods cut along its base, has stood in good order as a footway for some five years. They have also been used for filling in wooden wharves at Newport, where they stand the wash perfectly. There are, doubtless, many other such uses, which ingenuity would soon discover, should attention be thus directed. When we remember that India-rubber was for many years only known as a means of erasing pencil-marks, and that gutta-percha was, until very recently, only used for axe-handles, we shall be inclined to study new applications of old materials in a very hopeful spirit.

The following papers were presented, and most of them were read, but no copy of them has been furnished for publication: —

## I. MATHEMATICS AND PHYSICS.

1. On the Mean Distance from the Sun, Inclination of Orbit, and Equatorial Character of the Asteroid Planet. By Professor Stephen Alexander.
2. On the Physical Phenomena presented during the Solar Eclipse of May 26, 1854. By Professor Stephen Alexander.
3. Some Additions to the New Method of Astronomical Observations in R. Ascension and in Declination. By Professor O. M. Mitchel.
4. On Binocular Vision. By Professor W. B. Rogers.
5. On the Winds. By Captain Charles Wilkes.
6. On the Zodiacal Light. By Rev. George Jones.
7. On the Colored Projections from the Edge of the Sun, as observed during Solar Eclipses. By Professor Joseph Henry.
8. The Effect of the Gulf Stream on the Temperature of the Atlantic Coast. By Dr. James Wynne.

## II. CHEMISTRY, NATURAL HISTORY, AND GEOLOGY.

9. On the Method of analyzing the Sulphate, Arsenate, and Molybdate of Lead. By Professor J. Lawrence Smith.
10. On some Arrangements to facilitate Chemical Manipulations. By Professor R. E. Rogers.
11. Notice of Remarkable Specimens of Crystallized and Arborescent Gold, from California. By W. P. Blake.
12. On the Deposits of Fossil Microscopic Organisms at Monterey, California, with Specimens. By W. P. Blake.
13. Notes upon the Geology and Mineral Association of the Cinnabar Sulphuret of Mercury, of New Almaden, Cal., with Specimens. By W. P. Blake.
14. On the Stratagraphical Position of the Coal-bearing Rocks below the Upper Red Shale and Carboniferous Limestone of the Middle and Southern States. By Professor William B. Rogers.

15. On the Configuration of the Soil of New England. By Professor A. Guyot.

16. On the Occurrence of Proboscidon Remains in Wisconsin. By Edward Daniels.

17. On the Character of the Lead Deposits of the Upper Mississippi. By Edward Daniels.

18. On the Occurrence of Silicious Grits as Veinstones in the Lead Mines of Wisconsin. By Edward Daniels.

19. Some Observations on the Northern Outcrop of the Illinois Coal Formation. By Edward Daniels.

20. Contributions to our Knowledge of the Geology of Nebraska and the *Mauvaises Terres*. By Professor James Hall.

21. Notes upon the Genus Graptolithes. By Professor James Hall.

22. On the Development of the Septa in the Genus Baculites, from the extreme Young to the Adult State. By Professor James Hall.

23. On some Effects produced by the Trap on the adjoining Liasic Rocks of Virginia. By Professor W. B. Rogers.

24. Notes on the Geology of Western India. By Rev. Ebenezer Burgess.

25. Remarks on the Geological Formation of Table Mountain, Cape of Good Hope. By Rev. Ebenezer Burgess.

26. On the Metamorphic Rocks of Nahant, Mass. By Professor Louis Agassiz.

27. On Gradation among Polypi. By Professor Louis Agassiz.

28. On the System of Zoölogy. By Professor Louis Agassiz.

29. Notes on the Nature of the Coverings of the Seeds of Magnolia, and on the Diœcious Character of Species of Plantago. By Professor A. Gray.

30. Motions effected by Plants result from the Contractions of Cells. By Professor A. Gray.

31. On the Probability of a Decline in the Production of Gold. By J. D. Whitney.

32. On the Big-root of California, a new Genus of Cucurbitaceæ (Megarrhiza). By Professor John Torrey.

# EXECUTIVE PROCEEDINGS

OF THE

# PROVIDENCE MEETING, 1855.

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## HISTORY OF THE MEETING.

THE Ninth Meeting of the American Association for the Advancement of Science was held at Providence, R. I., commencing on Wednesday, August 15, and continuing through Wednesday, August 22.

The number of names registered in the book of members in attendance on this meeting was one hundred and sixty-six. Seventy-four new members were chosen, of whom fifty-eight have since accepted their appointment. Sixteen others have joined the Association by virtue of Rule 2 or 3. Four others paid, without signing the constitution. Ninety-three papers were presented, most of which were read, but only a part have been printed. Some were thought unworthy of publication, and, in other cases, copies have not been furnished by their authors.

The Meetings of the Association were held in the Halls of Brown University.

The Annual Address was delivered by the retiring President, Professor JAMES D. DANA, on Friday evening, August 17.

A Report on the Recent Progress of Organic Chemistry was read by Dr. WOLCOTT GIBBS, on Saturday morning, August 18.

No lengthened abstract of the proceedings, scientific and executive, of the Providence Meeting of the Association is necessary in this place, as they are contained in full in the papers and resolutions printed in this volume. The revisal of the constitution, and the codi-

fication of the various scattered resolutions, of a permanent character, passed since the organization of the Association, excited a brief debate, when the subject was postponed for another year.

The officers elected for the next meeting are Professor JAMES HALL, of Albany, President; Dr. B. A. GOULD, of Cambridge, General Secretary; and Dr. A. L. ELWYN, of Philadelphia, Treasurer. The Permanent Secretary, Professor JOSEPH LOVERING, of Cambridge, retains his office for three years from August, 1854.

The Association voted to hold their next meeting at Albany, N. Y., on Wednesday, the 20th of August, 1856, having received an invitation to visit that city from several prominent citizens.

During the meeting at Providence, the members of the Association, and their ladies, were elegantly entertained on different evenings as follows: — By President WAYLAND, on Wednesday, August 15th; by Z. ALLEN, Esq., and by Gen. E. DYER, on Thursday, the 16th; by JOHN C. BROWN, Esq., on Friday, the 17th; by JAMES Y. SMITH, Esq., Mayor of the City, on Monday, the 20th; and by DR. S. B. TOBEY, on Tuesday, the 21st.

On the afternoon of Wednesday, August 22, the members of the Association, and their ladies, were entertained at dinner by invitation of the Local Committee, and through the hospitality of the citizens of Providence. The company assembled in University Hall, and at 2 o'clock, P. M. proceeded thence to the table, which was spread under a beautiful tent upon the College green. After partaking of the bountiful repast, the members of the Association were briefly welcomed by Professor A. CASWELL, in behalf of the Local Committee, and the several votes of thanks, hereafter printed, were read, and, after appropriate remarks from members of the Association and citizens of Providence, were passed by acclammation. The members of the Association were compelled, by want of time, to decline an invitation to join in an excursion down the bay to Bristol Ferry.

Arrangements were also made by the Local Committee, which gave the members of the Association access to the following places: — University Library, Providence Athenæum, Butler Hospital, Swan Point Cemetery, City Reform School, State Prison, P. Allen & Sons' Print-Works (North End), Eagle Screw Factory, 21 Stevens Street (North End), Corliss and Nightingale's Steam-Engine Manufactory (North End), Providence Forge and Nut Company's Works (North

End), Gorham and Company's Silver Ware Manufactory, 12 Steeple Street, Providence Gas Works, Benefit Street (Lower End), Rolling Mill, Benefit Street (Lower End), Sackett, Davis, and Potter's Jewelry Manufactory, corner of Richmond and Friendship Streets, Providence Machine Company's Works, Eddy Street, New England Screw Factory, Eddy Street, Atlantic DeLaine Company's Mills, at Olneyville (now manufacturing cottons and cassimeres), and J. Dunnell and Company's Print-Works, Pawtucket.

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## RESOLUTIONS ADOPTED.

*Resolved*, That this Association regards the preparation of an Index of Papers on subjects of Mathematical and Physical Science, proposed in Lieutenant HUNT's communication to the Section of Mathematics and Physics, as one of the most important and valuable enterprises for advancing science which can now be undertaken, and that it would invite the co-operation of such persons as are able effectively to labor for this end.

*Resolved*, That the Committee on Standard Weights, Measures, and Coinage be authorized to communicate with other associations, or public bodies, or with individuals, in regard to the establishment of universal and permanent uniformity in weights, measures, and coinage; and be requested to report at the next meeting.

*Resolved*, That the Committee on Weights and Measures be instructed to correspond with Great Britain and France, and such other countries as may seem desirable, on the subject of Coinage; and to present a memorial to Congress, at its next session, in favor of adopting the decimal system of weights and measures.

*Resolved*, That the draught of the Constitution, proposed by the Committee appointed to revise the same, be laid over till the Albany meeting.

*Resolved*, That Professor A. D. BACHE and Professor JOSEPH LOVERING be a Committee to report to the Standing Committee in regard to the continuance or discontinuance of old Special Committees.

*Resolved*, That the following Committees be discharged: —

1. Committee to Memorialize the Legislature of Ohio on the Subject of a Geological Exploration of that State.

2. Committee to Memorialize Congress in Relation to a Geographical Department of the Congress Library.

3. Committee to Memorialize Congress for an Appropriation to enable Professor O. M. MITCHEL to perfect and apply his new Astronomical Apparatus.

4. Committee to take Proper Measures in Regard to the Annular Eclipse of May 26th, 1854.

*Resolved*, That the Standing Committee return their best thanks to the Permanent Secretary, for the very thorough manner in which he has executed the duties of his office; and congratulate the Association on the success of the able and energetic measures pursued by him.

*Resolved*, — 1. That the papers read at this meeting be referred to the Standing Committee, to determine in reference to their publication.

2. That the papers not accepted for publication be returned to their authors.

*Resolved*, That the Permanent Secretary be allowed to put the Proceedings of the Providence Meeting to press one month after the adjournment of the Association, and that 1,500 copies be printed.

*Resolved*, That the Permanent Secretary be directed to cause 300 extra copies of the Address of the retiring President to be struck off, and placed at the disposal of the author.

*Resolved*, That the Permanent Secretary be directed to cause 300 extra copies of the Report of DR. WOLCOTT GIBBS to be struck off, and placed at the disposal of the author.

*Resolved*, That the Standing Committee extend an invitation to foreign learned societies, and individuals devoted to science, to attend the annual meetings of the Association.

*Resolved*, That the next meeting of the Association be held at Albany, commencing on the third Wednesday of August [20], 1856.

*Resolved*, That the Standing Committee of the Association meet at the Delavan House in Albany, on Tuesday evening, August 19, at 9 o'clock, P. M., in order to make arrangements in advance to facilitate the business of the meeting.

*Resolved*, That the Local Committee for the Albany Meeting be requested to secure the services of Mr. PARKHURST, and a proper corps of assistants, if required, to give short-hand reports of the discussions at the meeting. In case Mr. PARKHURST cannot be obtained, that then the Local Committee shall be authorized to secure the services of the best phonographer to be found.

*Resolved*, That the Standing Committee be authorized to act for the Association in any matters of business which may not have been completed at the time of the adjournment of the Providence Meeting.

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RESOLUTIONS IN HONOR OF THE LATE HON. ABBOTT LAWRENCE OF BOSTON. Presented by PROFESSOR A. D. BACHE.

I RISE to make an announcement, and to offer a resolution of condolence in reference to the decease of one of the most munificent patrons of science in the United States, — the Hon. Abbott Lawrence, — whose career of beneficence has just been closed by death.

After struggling for eighteen months against disease, Mr. Lawrence died on Saturday last, at his residence in Boston, at the age of between sixty-two and sixty-three years.

Having in middle life acquired by his own exertions an ample fortune, Mr. Lawrence devoted his large means to the good works of charity, beneficence, and hospitality, and to the fostering of science, learning, and art.

It is chiefly as the founder of the Lawrence Scientific School of Harvard that I wish to dwell upon his claims to your consideration. At the outset he endowed that institution with the sum of fifty thousand dollars, and there is confidence that his will contains provision for giving still further development to this great work.

The light in which this endowment was regarded by the family of Mr. Lawrence, and which shows how nobly they are associated in his great and good deeds, is revealed by a letter from his brother Amos, which I take the opportunity to read to the Association.

"Wednesday Morning, June 9, 1847.

"DEAR BROTHER ABBOTT: — I hardly dare trust myself to speak what I feel, and therefore write a word to say, that I thank God I am spared to this day, to see accomplished by one so near and dear to

me this last, best work ever done by one of our name, which will prove a better title to true nobility than any from the potentates of the world. It is more honorable and more to be coveted than the highest public station in our country, purchased as these stations often are by timeserving. It is to impress on unborn millions the great truth, that our talents are trusts committed to us for use, and to be accounted for when the Master calls. This magnificent plan is the great thing you will see carried out, if your life is spared; and you may well cherish it as the thing nearest your heart. It enriches your descendants in a way that mere money never can do, and it is a better investment than any one you have ever made.

"Your affectionate brother,

"Amos.

"To Abbott Lawrence."

The success of that institution has been already very great, and within a few days of his decease Mr. Lawrence had the high gratification to receive the assurances of this from one of our colleagues best able to appreciate the results (Professor Peirce), who, having attended the annual examinations of the school, found such evidences of successful study, and ample and sound instruction, that he felt constrained to express to the dying patron of the School his convictions of the entire success of his judicious plans.

It will be recollected by some of the members of the Association, that Mr. Lawrence was selected by President Taylor as his Secretary of the Navy. This offer, however, he felt compelled to decline.

On visiting Washington, he told me that one regret which he had in declining the post was, that he should not have the opportunity to organize the Nautical Almanac, for which an appropriation had been made by Congress, but that he would recommend earnestly to his successor the plan which since has been so well executed.

As Minister to the Court of St. James, Mr. Lawrence had many opportunities of showing to scientific men his high appreciation of the career to which they were devoted. Those who visited Europe always found him ready to aid them in accomplishing the objects of their journey, and those who desired communication with Europeans were assisted by all the means in his power.

The science of the United States owes a debt of deep gratitude to Mr. Lawrence, which the resolutions I now present but feebly shadow forth.

*Resolved*, That the American Association for the Advancement of Science have heard with deep regret of the decease of the Hon. Abbott Lawrence, who, by the munificent foundation of the Lawrence Scientific School of Harvard University, has identified his name with the progress of science in the United States.

*Resolved*, That the members of the Association offer their sincere condolence to the bereaved family of Mr. Lawrence.

*Resolved*, That the President and Secretaries of the Association communicate these resolutions to the family of the deceased.

These resolutions, signed by the President and Secretaries of the Association, were transmitted to Mrs. Lawrence, with the following note from the Permanent Secretary: —

"Cambridge, September 11, 1855.

"While I have the honor officially to transmit to you the resolutions passed by the American Association for the Advancement of Science, in acknowledgment of the great public and private loss occasioned by the death of your late husband, the Hon. Abbott Lawrence, may I be permitted also to express to you my individual sympathy with you in your severe affliction.

"Very truly yours,

"JOSEPH LOVERING,

*Permanent Secretary*.

"MRS. ABBOTT LAWRENCE."

## CORRESPONDENCE.

Providence, July 20, 1855.

For several years extensive experiments have been made in France, upon a large scale, with the view of ascertaining how far the rivers of that country could be replenished with fishes, which of late had become very scarce. The experiments have been entirely successful. With such results before us, and when we hear daily how our rivers are losing their fishes, it would seem desirable that the Association should recommend, or at least countenance, the measures which are likely to be proposed in the State of New York, with reference to fisheries and artificial fecundation of fishes.

The motives for such exertions are the salubrity of that article of food, the usefulness of certain regulations to secure its production, and the advantage the practices employed in artificial fecundation afford to scientific investigations.

Scientific men, above all others, should be anxious to secure to the community an abundance of fish, when it is ascertained that no other article of food supplies so promptly, and so effectually, the waste of the brain arising from mental exertions.

Wherever artificial fecundation has been practised, fishes have become abundant, even where they had been scarce before. For more than one hundred years the breeding of fishes has been successfully practised in Germany, especially that of carps.

Finally, it is by artificial fecundation embryologists have recently obtained the most favorable opportunities of tracing their investigations.

Taking into consideration all these circumstances, it seems to me desirable that the Standing Committee offer a resolution to the Association, to the effect of approving the measure which the Legislature of New York may pass to promote pisciculture in that State.

L. AGASSIZ.

TO THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

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The Committee to whom the subject of the introduction of establishments for fish-breeding in this country was referred, beg leave to recommend, —

That a Committee be appointed to memorialize the Legislature of New York, with reference to the promotion of fish-breeding in that State.

JAMES D. DANA.

# REPORTS.

## 1. Report of Professor S. F. Baird, late Permanent Secretary of the American Association for the Advancement of Science, on the Distribution and Disposal of the Volumes of Proceedings.

The objects of the report will perhaps be best answered by taking up the volumes in succession, and giving a brief account of the circumstances attending their publication.

*First Meeting, Philadelphia*, 1848.—This volume was edited and published in Philadelphia, and distributed from that point to members. The extent of the edition is not known, but, as in the case of the Cambridge volume, it is understood that nearly all the members on the list received copies, irrespective of their having paid their annual fees. No statement of the distribution of this volume, as of the Cambridge and Charleston ones, having been made by the Secretary preceding the undersigned, he can only give the number of 286 copies as received by him from various sources. The number delivered to Professor Lovering amounts to 86 copies.

*Second Meeting, Cambridge*, 1849.—Of this volume, 700 copies were published by the Association, all of which were expended by issues to members, distribution to learned societies abroad, &c., no particulars of which are on record. The undersigned received no copies whatever from the previous Secretary of the Association. He however purchased from Munroe & Co., of Boston, 100 copies, at $1.00 each, with a few from other parties at $1.50; and collected between forty and fifty volumes from the Smithsonian Institution, Professor Henry, and others, who liberally gave back the copies they had received in return for extra subscriptions. Delivered to Professor Lovering 32 copies.

*Third Meeting, Charleston*, 1850.—This volume was published by the liberality of the city of Charleston, without expense to the Association, and copies given to all members who had paid their dues. From Mr. Herrick were received 184 copies, and others from Dr. Ravenel of Charleston, of which no account was sent, and the number cannot now be exactly ascertained, but is believed to have been about 300. Delivered to Professor Lovering 292 copies.

*Fourth Meeting, New Haven,* 1850. — Of this, the first volume published by the undersigned, 1,000 copies were issued; of these, 30 copies were lost on the steamboat on which they had been shipped for transmission to the Albany meeting. Delivered to Professor Lovering 274 copies.

*Fifth Meeting, Cincinnati,* 1851. — This volume was published by the citizens of Cincinnati, in an edition of 999 copies, of which 60 were retained by the Cincinnati Committee for subscribers to the publishing fund, 55 for other members of the Association, and 182 for the purpose of making up by their sale a balance due on the volume after the subscriptions had been collected. The remaining 702 copies were sent to the undersigned. Delivered to Professor Lovering 494 copies.

*Sixth Meeting, Albany,* 1851. — This volume was also published by subscription among the citizens of Albany, and 1,000 copies placed at the disposal of the Association. Of these, 374 copies were delivered immediately on their publication to members who had paid their dues; much the largest number ever issued in this way at any one time. Delivered to Professor Lovering 353 copies.

It is a difficult matter to get at the exact number of copies of the Proceedings issued to members, as no strict account of these was kept. The earlier volumes were distributed to nearly all the names recorded on the list, whether the parties had paid their annual dues or not. As this was found to encourage remissness in paying the annual assessments, the Association directed that the New Haven and succeeding volumes should be issued only to those who had paid their dues, providing also for the elimination, after due notice, of the names of delinquents. In this way a great saving was effected in the stock of publications, which thenceforward became a source of profit to the Association, instead of requiring the extra aid of a few liberal members to meet the expenses over and above the amount in the hands of the Treasurer.

The number of copies thus distributed for the two regular volumes (New Haven and Albany), after this order, has varied from three to four hundred, exclusive of sales of back volumes to new members, or to non-members, either directly, or through agents. Lists have been furnished from time to time by the Treasurer, of persons paying their dues, and consequently entitled to the corresponding volumes, or certificates furnished by him to parties have been presented and received

as vouchers of the same right. No minute record of the volumes so issued has been kept, as the stock on hand by actual count, added to the number sold, or distributed to foreign and domestic institutions (of which the accounts are carefully preserved), always furnishes the data for ascertaining the volumes thus expended.

One not inconsiderable expenditure of volumes has been in the number lost at meetings, by being carried away surreptitiously or accidentally from the office of the Association. It has been impossible to keep these books always in a safe place, or to exercise that constant supervision over them which would prevent this loss. In a single meeting, as many as twenty or thirty copies have gone in this way, as nearly as could be ascertained; taken, not by members in all probability, but by others, some of whom doubtless supposed these volumes intended for gratuitous distribution.

In addition to the copies of the volumes distributed to members and institutions, a considerable number has been sold by booksellers or agents, as mentioned in the accompanying statement, in the aggregate amounting to 693 volumes. The gross receipts by the Treasurer for these volumes have amounted to over 1,000 dollars, constituting no inconsiderable source of revenue, and, at the same time, putting it in the power of institutions and individuals, at home and abroad, not members, to procure the records of the Association.

Respectfully submitted,

SPENCER F. BAIRD.

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## APPENDIX A.

S. F. BAIRD in Account with Volumes of the Proceedings of the American Association.

| Dr. | | I. *Philadelphia.* | Cr. | |
|---|---|---|---|---|
| Rec'd from W. P. Hazard, | 172 | Sold, . . . | 105 | |
| " " E. C. Herrick, | 114 | In hands of Agents, | 25 | |
| | —— | European Distribution, | 27 | |
| | 286 | Issued to Members, say | 43 | |
| | | Sent Professor Lovering, | 86 | |
| | | | —— | 286 |

II. *Cambridge.*

| | | | | |
|---|---|---|---|---|
| Purchased of Munroe, . | 100 | Sold, . . . . | 60 | |
| Presented by Smithsonian Institution, and obtained in other ways, . . | 50 | With Agents, . . | 25 | |
| | | European Distribution, | 27 | |
| | | To Members, say . | 6 | |
| | | To Professor Lovering, | 32 | |
| | 150 | | | 150 |

III. *Charleston.*

| | | | | |
|---|---|---|---|---|
| From E. C. Herrick, . | 184 | Sold, . . . . | 123 | |
| From Ravenel, . . . . | ? | With Agents, . | 25 | |
| | | European Distribution, | 27 | |
| | | To Members, . . | ? | |
| | | To Professor Lovering, | 292 | |
| | | | | 467 |

IV. *New Haven.*

| | | | | |
|---|---|---|---|---|
| From Printer, . . | 1,000 | Sold, . . . . | 278 | |
| | | With Agents, . | 68 | |
| | | Lost by steamboat, . | 30 | |
| | | To Europ. Institutions, | 3 | |
| | | To Amer. " | 8 | |
| | | To Members, say . | 339 | |
| | | To Professor Lovering, | 274 | |
| | | | | 1,000 |

V. *Cincinnati.*

| | | | | |
|---|---|---|---|---|
| Edition published, . . | 999 | Sold, . . . . | 72 | |
| | | With Agents, . | 25 | |
| | | To Europ. Institutions, | 27 | |
| | | To Amer. " | 8 | |
| | | To Members, say . | 131 | |
| | | To Subscribers of $ 5, | 60 | |
| | | Kept by Cincin. Com. | 182 | |
| | | To Professor Lovering, | 494 | |
| | | | | 999 |

VI. *Albany.*

| | | | | |
|---|---|---|---|---|
| Edition published, . . | 1,000 | Sold, . . . . | 55 | |
| | | With Agents, . | 160 | |
| | | To Europ. Institutions, | 28 | |
| | | To Amer. " | 8 | |
| | | To Members, say | 396 | |
| | | To Professor Lovering, | 353 | |
| | | | | 1,000 |

## APPENDIX B.

*List of European Institutions to which Copies of the Proceedings of the American Association were distributed by S. F. Baird in* 1852 - 53.

| | Volumes. | | | | | |
|---|---|---|---|---|---|---|
| | I. | II. | III. | IV. | V. | VI. |
| *Stockholm*, — Kongliga Svenska Vetenskaps Akademien, . . . . . . . | * | * | * | | * | * |
| *Copenhagen*, — Kongel. danske Vidensk. Selskab, . . . . . . . . | * | * | * | | * | * |
| *Moscow*, — Soc. Imp. des Naturalistes, . | * | * | * | | * | * |
| *St. Petersburg*, — Acad. Imp. des Sciences, | * | * | * | | * | * |
| " Kais. Russ. Min. Gesellsch., | * | * | * | * | * | * |
| *Amsterdam*, — Acad. Royale des Sciences, | * | * | * | | * | * |
| *Haarlem*, — Holl. Maatschappij der Wetenschappen, . . . . . . . | * | * | * | | * | * |
| *Berlin*, — K. P. Akad. der Wiss., . . | * | * | * | | * | * |
| *Breslau*, — K. L. C. Akad. der Naturf., . | * | * | * | | * | * |
| *Franckfurt*, — Senckenbergische Gesellschaft, | * | * | * | | * | * |
| *Göttingen*, — Königl. Gesellschaft der Wiss., | * | * | * | | * | * |
| *Munich*, — K. B. Akad. der Wiss., . . | * | * | * | | * | * |
| *Prag*, — K. Böhm. Gesellschaft der Wiss., . | * | * | * | | * | * |
| *Vienna*, — K. Akad. der Wiss., . . | * | * | * | | * | * |
| *Bern*, — Allg. Schw. Gesellschaft, . . | * | * | * | | * | * |
| *Geneve*, — Soc. de Physique et d'Hist. Nat., | * | * | * | | * | * |
| *Bruxelles*, — Acad. Royale des Sciences, . | * | * | * | | * | * |
| *Liège*, — Soc. Royale des Sciences, . | * | * | * | | * | * |
| *Paris*, — Institut de France, . . . . | * | * | * | | * | * |
| *Turin*, — Accademia Reale delle Scienze, | * | * | * | | * | * |
| *Madrid*, — Real Acad. des Ciencias, . . | * | * | * | | * | * |
| *Cambridge*, — Camb. Philosophical Society, | * | * | * | | * | * |
| *Dublin*, — Royal Irish Academy, . . | | | | | | * |
| *Edinburgh*, — Royal Society, . . . . | * | * | * | * | * | * |
| *London*, — Board of Admiralty, . . . . | * | * | * | | * | * |
| " East India Company, . . | * | * | * | | * | * |
| " Museum of Practical Geology, . | * | * | * | * | * | * |
| " Royal Society, . . . . | * | * | * | | * | * |
| | 27 | 27 | 27 | 3 | 27 | 28 |

Copies of the fourth volume were purchased by the Smithsonian Institution, and presented to the above Institutions.

*American Institutions receiving Copies of the Proceedings of the American Association by Vote of the Association.*

| | Volumes IV. | V. | VI. |
|---|---|---|---|
| American Academy, *Boston*, . . . . . . | " | " | " |
| Natural History Society, *Boston*, . . . . . . | " | " | " |
| New York Lyceum, *New York*, . . . . . | " | " | " |
| Philadelphia Academy of Natural Sciences, *Philadelphia*, | " | " | " |
| American Philosophical Society, " | " | " | " |
| Western Academy of Natural Sciences, *Cincinnati*, . | " | " | " |
| Cleveland Academy of Natural Sciences, *Cleveland*, . | " | " | " |
| Smithsonian Institution, *Washington*, . . . . | " | " | " |

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*Report of the Committee to examine into the Distribution of Copies of Proceedings of the American Association for the Advancement of Science, by the late Permanent Secretary, Professor S. F. Baird.*

The undersigned, a Committee appointed for the purpose, have examined the report of the late Permanent Secretary of the American Association, in reference to the distribution of volumes of Proceedings in his charge, and find the account as satisfactory as the nature of such transactions will allow, and they fully accord to the late Secretary the commendation which they think he deserves for his management of the trust committed to his care.

Joseph Henry,
J. S. Hubbard.

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To the Standing Committee of the American Association for the Advancement of Science: —

The undersigned, a Sub-Committee to whom was referred the documents presented by the late Permanent Secretary, Professor Baird, would report, —

1st. That these documents consist of a statement of *estimates* of the number of volumes received and distributed, but without any vouchers.

2dly. Of a list of institutions to whom the Proceedings have been sent.

3dly. Of a certificate signed by Professors Joseph Henry and J. S. Hubbard, that the accounts seem as satisfactory as the nature of the case permits, and according the commendation which they think he deserves.

The Sub-Committee do not feel themselves called upon to express any judgment in the premises.

JAMES D. DANA,
B. A. GOULD, JR.

Providence, August 19, 1855.

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## 2. REPORT OF THE COMMITTEE ON THE SOLAR ECLIPSE OF MAY 26, 1854.

THE Committee on the Solar Eclipse of May 26, 1854, respectfully report, that they attended to the duties confided to them, distributing as widely as possible the information in regard to it, and making extended arrangements for observation. The unfavorable character of the weather on the day, in that portion of the United States in which the eclipse was annular and central, is well known to the members. The observations collected have been published in the Astronomical Journal, and the Committee now request to be discharged.

A. D. BACHE, *Chairman.*

Providence, August 22, 1855.

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## 3. REPORT ON MR. BASSNETT'S THEORY OF STORMS. BY PROFESSOR JOSEPH HENRY.

PROFESSOR Henry presented the following verbal report on Mr. Bassnett's Theory of Storms.

Professor Henry stated that Mr. Bassnett's theory had been tested by the Committee, by observing the weather, and noting its correspondence or want of correspondence with Mr. Bassnett's predictions. The predictions of the theory were verified during the first ten days tolerably well, but were found worthless during the remaining time of observation, or for nearly two months.

4. Report of the Committee on Dr. Brainerd's Paper.

The Committee to whom the question respecting the non-publication of Dr. Brainerd's paper was referred would report, —

*First.* That the paper of Dr. Brainerd was withdrawn from the list of papers for the Cleveland Volume, by the regular and authorized action of the Association.

*Second.* That the character of the paper was such, — its conclusions so erroneous, and its reasonings so false, — that any other action would have been wanting in fidelity to the interests of the Association and the science of the country.

James D. Dana,
Benjamin Peirce.

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## INVITATIONS.

To the President of the Association: —

The Local Committee invite the Association to join them in an excursion down the Bay to Bristol Ferry, on one day during the session. Tuesday or Wednesday of next week will be convenient.

Very respectfully,
A. Caswell, *Chairman.*

**Saturday, August 18, 1855.**

In reply to this invitation, it was resolved, —

That the Association presents its sincere thanks to the Local Committee and citizens for their kind invitation, and regrets exceedingly that the want of time will prevent the members from accepting it.

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To the President of the Scientific Association: —

The Committee of Reception have the pleasure of inviting the members of the Association for the Advancement of Science, together with their ladies in attendance, to a Complimentary Dinner, on Wednesday, the 22d, at 2 P. M.

For the Committee,
A. Caswell.

**Monday, August 20, 1855.**

Rooms of the Providence Young Men's Christian Association,
No. 56 Broad Street, August 11th, 1855.

Members of the Scientific Association: —

Gentlemen, — It becomes my pleasing duty to inform you, that at the meeting of the Board of Managers of this Association, holden on the 9th instant, it was voted, —

"That the members of the Scientific Association be invited to visit our Library and Reading-Room as often as may suit their convenience during their session in our city."

N. B. — Rooms open from 9 A. M. to 9½ P. M.

Respectfully yours,

William C. Mills,
*Sec. of Board of Managers of the P. Y. M. C. Association.*

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Providence, August 17, 1855.

Sir, — The Cabinet and Library of the Rhode Island Historical Society will be open for inspection by the members of the American Scientific Association, on the afternoon of Monday, the 20th instant.

Any members of the Association who are interested in historical investigations can obtain ready admission to the rooms at any other time, by application to any member of the Society.

Very respectfully, your obedient servant,

Albert G. Greene, *President R. I. Hist. Society.*

Prof. John Torrey, *President Amer. Scientific Association.*

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To the President of the American Association for the Advancement of Science: —

Dear Sir, — The Providence Franklin Society, a body especially devoted to the study of physical science, has voted to invite the members of your Association to visit its Cabinet during your session. A Committee, of which the President of the Society is chairman, is charged with the agreeable duty of communicating this invitation.

We shall be happy to meet the members of the Association, and any others who may favor us with a visit, on the afternoons of Friday and Saturday, the 17th and 18th of August, at which time some of

our Committee will be present. The Cabinet will be accessible at any other time, on application to any members of the Society.

On behalf of the Committee,

CHARLES W. PARSONS,

*President of the Providence Franklin Society.*

Providence, Cabinet of the Society, 20 North Main Street (up stairs), August 15, 1855.

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Providence Athenæum, August 14, 1855.

DEAR SIR, — I have the pleasure of enclosing to you, to be communicated, the vote of this Institution, tendering the use of its Rooms and Library to the members of the American Association for the Advancement of Science, while in this city.

WM. G. PATTEN, *Vice-President.*

DR. WOLCOTT GIBBS, *General Secretary of the American Association for the Advancement of Science, Providence.*

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Providence Athenæum, August 6, 1855.

*Voted*, That the members of the " American Association for the Advancement of Science " be authorized and invited to visit and use the Library of the Athenæum, and its Rooms, during the session of the Association about to be held in this city.

JOHN GORHAM, *Secretary.*

WM. G. PATTEN, *Vice-President.*

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## REPORT OF THE PERMANENT SECRETARY.

THIS report is made by the Secretary in anticipation of the adoption of the second clause of Article 20 of the new Constitution to be proposed, which requires a statement of " the business of which he has had charge since the last meeting of the Association." This business has consisted, — 1. of general correspondence; 2. of notification of their election to new members, and of the issue of the circular for the Providence meeting; 3. of the preparation, publica-

tion, and distribution of the Washington volume, and of large extra editions of Professor Peirce's Address, and Dr. B. A. Gould's Eulogy; and 4. of the collection of assessments, and the payment of bills.

I. Under the first head, the Secretary refers to the correspondence with the Minister of the Chilian Government, and with Professor G. B. Airy, of the Royal Observatory of Great Britain, contained in the Washington volume. He also states that the general correspondence consists of two hundred and eleven letters, all of which are on file, and all of which have received an answer when necessary.

II. Under the second head, the Secretary states that he availed himself of the opportunity afforded by the issue of the circular for the Providence meeting, to send to each member of the Association the amount of his indebtedness, — an innovation which the Secretary thinks will be justified by the propriety of the act, as well as by the financial result.

III. Under the third head it is to be stated, that fifteen hundred copies of the Washington volume have been printed. This volume consists of three hundred and seventy-two pages, with nine wood-cuts, and six large maps. The whole edition has involved an expense of one thousand dollars, or about sixty-seven cents *per copy*.

IV. Under the fourth head it is to be remarked, that much of the financial labor must in *fact*, as it does by *law*, fall upon the Permanent Secretary. *At* the Washington meeting, and *since* that meeting, down to the time when the circular for the present meeting was issued, the amount of five hundred and ninety-seven dollars and twenty-five cents was collected by the Secretary, in the form of assessments, and one hundred dollars and seventy-eight cents by the sale of publications. This has been expended for the purposes of the Association, as well as eight hundred dollars received directly from the Treasurer. The items, with vouchers, will be found in the register of the account current which the Secretary has opened with the Association.

Since the issue of the circular for the Providence meeting, down to August 21 (an interval of only one month), the Secretary has received assessments to the amount of eleven hundred and seventy-six dollars and fifty cents, or double the amount received during the preceding fifteen months. At the same time it remains to be stated, that there still exists a large sum of indebtedness to the Association; amounting, on a rough estimate, to five thousand dollars. The Association

now numbers one thousand and twenty-three members. Three dollars from each would pour into the treasury three thousand and sixty-nine dollars annually. The Secretary proposes to issue, after a suitable interval, a second circular to those who remain delinquent, and then to execute the law contained in Rule 19 of the old Constitution, or Rule 23 of the new Constitution printed by the Committee.

If the eleven hundred and eighty-six dollars and fifty cents just collected be added to the six hundred and thirty dollars and fifty-eight cents which appears, by the accompanying report of the Treasurer, to be the previous balance in the treasury, it gives a sum of one thousand eight hundred and seventeen dollars and eight cents with which to begin another financial year.

The probable expenses for that year may be loosely estimated as follows: —

| | |
|---|---|
| Salary of the Permanent Secretary, . . . . | $ 300 |
| Publication of the Providence volume, . . . | 1,000 |
| Republication of the Cleveland volume, . . . | 700 |
| Total, . . . . | $ 2,000 |

The sum total, which is exclusive of thirty-seven and a half dollars just paid by order of the Standing Committee to Mr. Brainerd for lithographing and printing Blodget's map, and of the expenses of the Providence meeting, and all other incidentals accruing during the current year, exceeds by one hundred and eighty-three dollars the money in the treasury. But it is hoped, that, by pressing vigorously the work of collection, the Association may be saved from pecuniary embarrassment, without restricting its publications.

In conclusion, the Secretary requests that his report and accounts may be audited by a Sub-Committee of the Standing Committee.

Respectfully submitted by

JOSEPH LOVERING,
*Permanent Secretary.*

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## REPORT OF THE AUDITORS.

THIS certifies that we have this day examined the above account of the Permanent Secretary, comparing the credits with the Treasurer's

account, and with the receipt-book of the Secretary, and the debits with the several vouchers, and find the whole correct, and the balance of one hundred and eleven dollars and ninety-six cents properly credited in the next account.

JOHN JOHNSTON, } *Auditors.*
JAMES HALL, }

Providence, August 24, 1855.

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## REPORT OF THE TREASURER.

Since the meeting at Washington in April, 1854, the Treasurer has received from G. P. Putnam thirty-five dollars; from S. F. Baird, one hundred and twenty-nine dollars and forty-eight cents; from J. M. Gilliss, one hundred and forty-two dollars and forty-seven cents; from assessments, ninety dollars and ninety cents: in all three hundred and ninety-seven dollars and eighty-five cents.

During the same time he has sent to Professor Lovering eight hundred dollars, and paid Brainerd and Burridge's bill for wood-cuts for the Cleveland volume, one hundred and nineteen dollars and seventy-five cents. Besides, there has been a discount of thirty-five cents for collecting.

The total amount, taken from the whole sum paid into the treasury since the Albany meeting, which is fifteen hundred and sixty-eight dollars and thirty-three cents, leaves in the hands of the Treasurer, at the commencement of the present meeting, six hundred and twenty dollars and fifty-eight cents.

A. L. ELWYN,
*Treasurer.*

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## VOTES OF THANKS.

*Resolved*, That the sincere thanks of the members of the Association be returned to the Trustees, President, and Professors of Brown University, for the cordial welcome which they have given, and for the ample accommodations afforded in the College buildings for the meetings of the Sections and Committees.

*Resolved*, That a set of the Volumes of the Proceedings of the Association be presented to the Library of Brown University.

*Resolved*, That the thanks of the Association be tendered to the Local Committee, and especially to its Chairman and Secretary, for their constant kindness and attention; and for their judicious and excellent arrangements both before and during the meeting.

*Resolved*, That the thanks of the Association be tendered to the numerous Societies, Libraries, and Manufacturing Establishments which have extended invitations to its members.

*Resolved*, That the thanks of the Association be tendered to the Benevolent Street Congregational Society, for the use of their church for the delivery of the Address of the retiring President, Professor J. D. Dana.

*Resolved*, That the thanks of the Association be tendered to the Railroad and Steamboat Companies who have offered free return tickets to members in attendance at this meeting.

*Resolved*, That the thanks of the members of the Association be tendered to the Citizens of Providence, whose private hospitality has been so freely and so munificently extended during our whole sojourn in their beautiful city.

*Resolved*, That the thanks of the Association be tendered to the Citizens of Providence, for the most noble and generous entertainment offered to its members on August 22.

*Resolved*, That a set of the Volumes of the Proceedings of the Association be presented to the Providence Athenæum.

# REPORT OF REMARKS

OFFERED ON OCCASION OF THE

# RESOLUTIONS INTRODUCED BY PROF. A. D. BACHE,

IN HONOR OF

# THE HON. ABBOTT LAWRENCE.

---

Mr. Samuel B. Ruggles rose to second the resolutions. He concurred most cordially in the judicious and eloquent tribute paid by Professor Bache to the private virtues and public services of Mr. Lawrence, and would only advert, in addition, to the position he had occupied in respect to American science, as rendering the proposed expression of feeling by this Association peculiarly appropriate.

Mr. Lawrence was probably the most important of the many important links which bind this Association to the community around it. In truth, he was the very type of that great and generous portion of the American public, ready and willing, at all times, to lend their hands, and heads, and hearts, and purses to the support of science. Nay, more, Mr. Lawrence stood forth a living exponent of the wide-spread opinion now pervading the American mind, that collegiate education is radically defective. He saw and felt, what so many others are beginning to see and feel, that man was made to study Nature; that physical science has become a positive necessity in any enlightened scheme of instruction; that the hitherto undisputed sway of mere language, of quiddities and verbal subtilties, has passed away. In a word, in Abbott Lawrence the fundamental idea was made incarnate, that men, to be men, must study not only *words*, but *things*.

Mr. Ruggles said that, for one, he held the charge that the com-

munity in general was indifferent to the necessity of the highest culture, to be wholly unfounded. On the contrary, the public desired and demanded a more comprehensive education, one more suited to their best and highest interests and necessities; not a narrow teaching drawn from the mouldering cloisters of dark and bygone ages, but a full, fresh, living volume of instruction, both in science and in letters, enlarged, modernized, and adapted to the century and to the civilization in which we are actually existing.

Mr. Ruggles said it had been his good fortune frequently to hear from Mr. Lawrence full and animated expositions of his views on this all-important point, — and it was but due to his memory now to bear testimony to the strong, manly sense, the practical sagacity, the noble, ample patriotism, which he carried into the whole subject. His broad and enlightened vision had enabled him to discern in this young empire of ours a new people, placed by the Providence of God on a new and all but untrodden continent, here to build up a new world by the fullest development and best exertion of all their physical, intellectual, and moral powers. Taking such a view, how could Mr. Lawrence think any education sufficient or suitable which should be devoted all but exclusively to languages and metaphysics, and failed to include a thorough study of the vast material Universe, with all its varied and majestic concords, its mighty and beneficent powers and agencies? Convinced of the wretched short-comings in this respect of most of our existing colleges, Mr. Lawrence founded and endowed, on a scale of requisite amplitude, the Scientific School at Cambridge, bearing his honored name; — and there it will stand, for coming ages, and as long as the educational history of our country shall endure, the precursor and model of kindred establishments, to be scattered broadcast throughout our favored land. It is not for this Association to add to the large and honest renown of their lamented patron, associate, and friend. He has himself sown the seed of his own ample and glorious harvest; for where, in all the broad expanse of our continental Union, from the Atlantic to the Pacific, is there a community or hamlet so small or remote as not to know and pronounce the name of Abbott Lawrence as the most sagacious, patriotic, and munificent patron of American science?

Dr. Wayland could hardly let these resolutions pass without rising to say a single word. It so happened that Mr. Lawrence was kind

enough to converse with him on this subject when he was organizing this School, and he was very much struck, as his friend Mr. Ruggles was also, with the largeness of his views, the clearness of his conceptions, and with the distinct knowledge that he had of what he was doing. He had a distinct object in view; his object was to commence an institution which should be a type of other institutions that should spread the blessings of science throughout our country in a way in which it had not before been spread abroad. He looked upon him (Mr. Lawrence) as a type, as Mr. Ruggles had said, of what was to be. He had set an example for men of wealth in this country. While Boston would always be proud of the name of Lawrence, there would be other Lawrences arising in New York, in Philadelphia, in all our large cities, — a train of men that would do honor to the country and to human nature. But however large this train might be, however noble and however magnanimous, they would all date from the name of Lawrence, — they would all be the Lawrences of this country. He believed that no honor which they could confer would be really adequate to the noble, high-minded, patriotic effort of this man, whom all felt honored by claiming as their fellow-citizen.

Professor Peirce would not have it thought, because none of the tributes which had been paid Mr. Lawrence were from his own State, that he was not appreciated at home. He had been universally beloved and respected in his own State. All his friends and neighbors felt him to be the source of more goodness in his native city than perhaps any other man ever was.

Professor Silliman, senior, as the oldest member of this Association, begged also to offer his word of tribute to Mr. Lawrence, whom he was proud to claim as an old and valued friend. Upwards of twenty years ago, and while modern geology had to contend with bitter religious prejudices, Abbott Lawrence headed the list of the intelligent citizens of Boston willing to examine the wonders of Nature, and adore the wisdom of the Creator as exhibited in his material creation. Mr. Lawrence had a devout but fearless spirit, and did not hesitate to read the revelations of God, as well in his works as in his Word; displaying in this, as in all his other traits, the breadth and freedom and liberality of his manly nature.

The Association then adopted the resolutions unanimously, the members all rising, and with evident emotion.

## ACCOUNT OF THE

Dr. AMERICAN ASSOCIATION *in*

| | |
|---|---|
| Freight on seven boxes from Washington, . . . . | $ 10.33 |
| " " " Boston, . . . . . . | 2.00 |
| Paid for storing Proceedings, . . . . . . . . | 1.25 |
| Two packages from S. F. Baird, . . . . . . | 2.62 |
| Box " " . . . . . . . | 3.37 |
| Printed notices of election, . . . . . . . | 2.00 |
| Circulars for Providence meeting, . . . . . . . | 20.00 |
| Postage on them, . . . . . . . . . . . | 10.50 |
| Eclipse circulars, . . . . . . . . . . . | 3.75 |
| Paper for Washington Volume, . . . . . . | 336.38 |
| Printing " " . . . . . . . | 444.60 |
| Wood-cuts, . . . . . . . . . . . . | 23.50 |
| Redfield's Map, . . . . . . . . . . . | 15.00 |
| Index, . . . . . . . . . . . . . | 5.00 |
| Paid for publishing Paper on the Eclipse, in Gould's Journal, | 43.94 |
| Extra copies of Peirce's Address, . . . . . . | 37.94 |
| Binding them, . . . . . . . . . . . | 21.12 |
| Envelopes for them, . . . . . . . . . | 2.00 |
| Extra copies of Gould's Eulogy, . . . . . . . | 16.50 |
| Binding them, . . . . . . . . . . . . | 7.60 |
| Permanent Secretary's salary, . . . . . . . | 300.00 |
| Expenses to Washington, . . . . . . . . . | 67.50 |
| Postage, . . . . . . . . . . . . . | 9.17 |
| Balance to next account, . . . . . . . . . | 111.96 |
| | $ 1,498.03 |

*Cambridge, August* 1, 1855.

## PERMANENT SECRETARY.

*Account with* JOSEPH LOVERING. Cr.

| | |
|---|---|
| Subscriptions received at Washington, . . . . . | $ 547.25 |
| Subscriptions received afterwards, to July 1, 1855, . . | 50.00 |
| Received from T. Walker, . . . . . . . . | 3.00 |
| " from J. Bartlett, . . . . . . . . . | 5.68 |
| " from Pottsville Association, . . . . . | 11.25 |
| " from Putnam & Co., . . . . . . . . | 80.85 |
| " Salary from the Treasurer, . . . . . | 300.00 |
| " Draft from the Treasurer, . . . . . . | 500.00 |
| | $1,498.03 |

## STOCK ACCOUNT OF THE PERMANENT SECRETARY.

*Volumes distributed or sold.*

| Volumes | I. | II. | III. | IV. | V. | VI. | VIII. |
|---|---|---|---|---|---|---|---|
| DELIVERED TO | | | | | | | |
| Jared Sparks, . . | | * | * | * | * | * | |
| John McRae, . | | | * | * | * | * | |
| Mitchel King, . . | | | | * | * | * | |
| H. I. Bowditch, . | * | | * | | * | * | |
| Isaac M'Conihe, . | | | | | * | | |
| J. H. Gibbon, . | | | | | | * | |
| Thomas Hill, . . | * | | | * | * | | |
| Isaac Lea, . . | | | | | | * | |
| James Hayward, . | | | | | * | | |
| W. J. McAlpine, . | | | | | | * | |
| F. Mauran, . . | | | | * | * | * | |
| Brown University,‡ | * | | * | * | * | * | * |
| Boston Society of Natural History, . . | | | | | | | * |
| Boston Athenæum, | | | | | | | * |
| American Academy, . | | | | | | | * |
| Harvard College, . | | | | | * | * | * |
| Elwyn's order, . . | * | * | * | * | * | * | |
| S. P. Lathrop, . | * | * | * | * | * | * | |
| Pottsville Association,† | * | * | * | * | * | * | * |
| Ovid Plumb,† . | | | | | | | * |
| Robert Townsend,† . | | | | | | | * |
| F. H. Smith,† . | | | | | | | * |
| J. B. Holland,† . . | | | | | | | * |
| George Suckley,† . | | | | | | | * |
| N. K. Davis,† . . | | | | | | | * |
| NewYork State Library,† | | | | | | | * |
| E. P. Prentice,‡ . . | | | | | | * | |
| W. F. Webster,‡ . | | | | | | | * |
| G. B. Paine,‡ . . | | | | | | | * |
| F. Paine,‡ . . | | | | | | | * |
| J. T. Caswell,‡ . . | | | | | | | * |
| Members, . . | | | | | | | 383 |
| G. P. Putnam & Co., . | | | | | | | 21 |
| Munroe & Co., . | | | | | | | 25 |
| Total, . . | 6 | 4 | 7 | 9 | 13 | 14 | 446 |

† Sold. ‡ By order of the Association.

# BALANCE OF STOCK.

| Volumes | I. | II. | III. | IV. | V. | VI. | VIII. |
|---|---|---|---|---|---|---|---|
| Received from S. F. Baird, . . . | 86 | 32 | 292 | 274 | 494 | 353 | 1483* |
| Delivered to members or sold, . . | 6 | 4 | 7 | 9 | 13 | 14 | 446 |
| Remaining, . . | 80 | 28 | 285 | 265 | 481 | 339 | 1037 |
| Received from E. N. Horsford, . . | 4 | 1 | | | | | |
| From Munroe & Co., | | 25 | | | | | |
| Balance, Mar, 20, 1856, | 84 | 54 | 285 | 265 | 481 | 339 | 1037 |

## ACCOUNT OF G. P. PUTNAM & CO. WITH THE ASSOCIATION.

*Volumes on hand.*

| Volumes | I. | II . | III. | IV. | V. | VI. | VIII. | Value. |
|---|---|---|---|---|---|---|---|---|
| January 1, 1854, . | 25 | 25 | 25 | 68 | 25 | 160 | | $ 442.50 |
| January 1, 1855, . | 18 | 18 | 18 | 72 | 18 | 160 | | $ 359.36 |
| January 1, 1856, . | 19 | 19 | 19 | 68 | 10 | 157 | 20 | $ 374.38 |

| | |
|---|---|
| Due to the Association for Volumes sold, . . . . . | $ 68.15 |
| Due to the Association for 21 copies of Volume VIII., . | 31.50 |
| | $ 99.65 |
| Due from the Association for Volumes I. – VI. delivered to N. K. Davis, . . . . . . . . . . | 7.51 |
| | $ 92.14 |
| Paid to J. Lovering's order, . . . . . . . . . | 80.85 |
| Now due, . . . . . . . . . . . | $ 11.29 |

*March* 20, 1856.

* These were received from the printer.

# INDEX.

# PROCEEDINGS

OF

# THE AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE.

**TENTH MEETING,**

HELD AT ALBANY, NEW YORK,

AUGUST, 1856.

BOSTON MEDICAL
JUL 18 1892
LIBRARY ASS'N.

CAMBRIDGE:
PUBLISHED BY JOSEPH LOVERING.
NEW YORK: G. P. PUTNAM & CO.
1857.

188,826
Nov. 27, 1875

EDITED BY

JOSEPH LOVERING,

*Permanent Secretary.*

CATALOGUED
JUL 18 1892
E. H. B.

CAMBRIDGE:

PART I. METCALF AND CO., PRINTERS. — PART II. ALLEN AND FARNHAM, PRINTERS.

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## COMMUNICATIONS.

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#### MATHEMATICS.



#### II. ASTRONOMY.

## III. PHYSICS AND CHEMISTRY.



## IV. PHYSICS OF THE GLOBE.

## V. METEOROLOGY.



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# PART II.

## B. NATURAL HISTORY.

### I. GEOLOGY AND GEOGRAPHY.

## C. PRACTICAL SCIENCE.

### I. MECHANICS.



### II. MISCELLANEOUS.



## EXECUTIVE PROCEEDINGS.

# OFFICERS OF THE ASSOCIATION

AT THE

# ALBANY MEETING.

---

Prof. James Hall, *President.*
Prof. Joseph Lovering, *Permanent Secretary.*
Dr. B. A. Gould, Jr., *General Secretary.*
Dr. A. L. Elwyn, *Treasurer.*

*Standing Committee.*

| | |
|---|---|
| Prof. James Hall, | Prof. A. D. Bache, |
| Prof. Joseph Lovering, | Prof. Alexis Caswell, |
| Dr. B. A. Gould, Jr., | Prof. Jeffries Wyman, |
| Dr. A. L. Elwyn, | Dr. John L. LeConte, |
| Prof. John Torrey, | Sir William E. Logan, |
| Prof. Wolcott Gibbs, | Prof. J. H. C. Coffin, |

*Local Committee.*

G. Y. Lansing, *Chairman.*

S. B. Woolworth,
John E. Gavit,
John Paterson, } *Secretaries.*

| | |
|---|---|
| Gov. Myron H. Clark, | Ezra P. Prentice, |
| Thomas W. Olcott, | John V. L. Pruyn, |
| John N. Campbell, | Thomas Hun, |

STEPHEN VAN RENSSELAER,
GIDEON HAWLEY,
WILLIAM B. SPRAGUE,
AMASA J. PARKER,
B. P. JOHNSON,
JOEL T. HEADLEY,
JAMES H. ARMSBY,
ERASTUS CORNING,
DANIEL D. BARNARD,
I. N. WYCKOFF,
THURLOW WEED,
IRA HARRIS,
AMOS DEAN.

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# SPECIAL COMMITTEES.

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## A. COMMITTEES CONTINUED FROM FORMER MEETINGS.

*Committee to Memorialize the Legislature of Ohio on the Subject of a Geological Exploration of that State.*

Dr. J. P. KIRTLAND, Cleveland.
Gov. S. P. CHASE, Columbus.
Hon. THOMAS ERVING, Lancaster.
Judge GEORGE HOADLEY, Jr., Cincinnati.
Gen. C. B. GODDARD, Zanesville.
Pres. J. W. ANDREWS, Marietta.
Prof. JOSEPH HENRY, Washington.
Prof. J. D. DANA, New Haven.
Prof. LOUIS AGASSIZ, Cambridge.

*Committee to Report in Relation to Uniform Standards in Weights, Measures, and Coinage.*

Prof. A. D. BACHE,
Prof. JOSEPH HENRY,
Prof. J. H. ALEXANDER,
Prof. JOHN F. FRAZER,
Prof. WOLCOTT GIBBS,
Prof. BENJAMIN PEIRCE,
Prof. JOHN LECONTE,
Prof. W. B. ROGERS,
Dr. J. H. GIBBON,
Dr. B. A. GOULD, Jr.,
Prof. J. LAWRENCE SMITH,
Prof. R. S. McCULLOCH.

*Committee to Audit the Accounts of the Treasurer, and Permanent Secretary.*

Prof. J. H. C. Coffin, | Dr. J. L. LeConte.

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## B. New Committees.

*Consulting Committee on the Publication of the Albany Proceedings.*

Prof. Benjamin Peirce, | Prof. E. N. Horsford.
Prof. Louis Agassiz,

*Committee to Memorialize the Legislature of New York in Reference to Fish-Breeding.*

Prof. Louis Agassiz, | Prof. J. D. Dana.

# OFFICERS OF THE MONTREAL MEETING.

---

Prof. J. W. Bailey, *President.*
Prof. Alexis Caswell, *Vice-President.*
Prof. Joseph Lovering, *Permanent Secretary.*
Dr. John Leconte, *General Secretary.*
Dr. A. L. Elwyn, *Treasurer.*

*Standing Committee.*

Prof. J. W. Bailey,
Prof. Joseph Lovering,
Prof. John Leconte.
Dr. A. L. Elwin,
Prof. James Hall,
Dr. B. A. Gould, Jr.

*Local Committee.*

Sir William E. Logan, *Chairman.*

The Mayor of the City,
The President of the Board of Trade,
The President of the Natural History Society,
Sir Louis LaFontaine,
Hon. P. J. O. Chauveau,
L. H. Halton, Esq.,
H. Lyman, Esq.,
Hon. Judge Day,
A. A. Donan, Esq.,
Hon. P. D. Beaujeu.

# MEETINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

| | Place. | Date. | President. | General Secretary. | Permanent Secret'y. | Treasurer. |
|---|---|---|---|---|---|---|
| 1st Meeting, | Philadelphia, Pa., | September 20, 1848, | W. C. Redfield, Esq., | Prof. Walter R. Johnson, | . . . | Prof. J. Wyman. |
| 2d " | Cambridge, Mass., | August 14, 1849, | Prof. Joseph Henry, | Prof. E. N. Horsford, | . . . | Dr. A. L. Elwyn. |
| 3d " | Charleston, S. C., | March 12, 1850, | Prof. A. D. Bache,* | Prof. L. R. Gibbes,* | . . . | Dr. St. J. Ravenel.* |
| 4th " | New Haven, Ct., | August 19, 1850, | Prof. A. D. Bache, | E. C. Herrick, Esq., | . . . | Dr. A. L. Elwyn. |
| 5th " | Cincinnati, Ohio, | May 5, 1851, | Prof. A. D. Bache, | Prof. W. B. Rogers, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 6th " | Albany, N. Y., | August 19, 1851, | Prof. L. Agassiz, | Prof. W. B. Rogers, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 7th " | Cleveland, Ohio., | July 28, 1853, | Prof. Benj. Peirce, | Prof. J. D. Dana, | Prof. S. F. Baird, | Dr. A. L. Elwyn. |
| 8th " | Washington, D.C., | April 26, 1854, | Prof. J. D. Dana, | Prof. J. Lawrence Smith, | Prof. J. Lovering, | Dr. J. L. LeConte.* |
| 9th " | Providence, R. I., | August 15, 1855, | Prof. John Torrey, | Prof. Walcott Gibbs, | Prof. J. Lovering, | Dr. A. L. Elwyn. |
| 10th " | Albany, N. Y., | August 20, 1856, | Prof. James Hall, | Dr. B. A. Gould, Jr., | Prof. J. Lovering, | Dr. A. L. Elwyn. |

* In the absence of the regular officer.

# CONSTITUTION OF THE ASSOCIATION.*

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### OBJECTS.

THE Association shall be called "The American Association for the Advancement of Science." The objects of the Association are by periodical and migratory meetings, to promote intercourse between those who are cultivating science in different parts of the United States; to give a stronger and more general impulse, and a more systematic direction to scientific research in our country; and to procure for the labors of scientific men increased facilities and a wider usefulness.

### MEMBERS.

RULE 1. Members of scientific societies, or learned bodies having in view any of the objects of this Association, and publishing transactions, shall be considered members on subscribing these rules.

RULE 2. Collegiate professors, also civil engineers and architects who have been employed in the construction or superintendence of public works, may become members on subscribing these rules.

RULE 3. Persons not embraced in the above provisions may become members of the Association upon recommen-

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* Adopted August 25, 1856, and ordered to go into effect at the opening of the Montreal Meeting.

dation in writing by two members, nomination by the Standing Committee, and election by a majority of the members present.

### OFFICERS.

RULE 4. The officers of the Association shall be a President, Vice-President, General Secretary, Permanent Secretary and Treasurer. The President, Vice-President, General Secretary and Treasurer, shall be elected at each meeting for the following one; — the three first-named officers not to be reëligible for the next two meetings, and the Treasurer to be reëligible as long as the Association may desire. The Permanent Secretary shall be elected at each second meeting, and also be reëligible as long as the Association may desire.

### MEETINGS.

RULE 5. The Association shall meet, at such intervals as it may determine, for one week or longer — the time and place of each meeting being determined by a vote of the Association at the previous meeting; and the arrangements for it shall be intrusted to the officers and the Local Committee.

### STANDING COMMITTEE.

RULE 6. There shall be a Standing Committee, to consist of the President, Vice-President, Secretaries, and Treasurer of the Association, the officers of the preceding year, the permanent chairmen of the Sectional Committees, after these shall have been organized, and six members present from the Association at large who shall have attended any of the previous meetings, to be elected upon open nomination by ballot on the first assembling of the Association. A majority of the whole number of votes cast to elect. The General Secretary shall be Secretary of the Standing Committee.

The duties of the Standing Committee shall be, —

1. To assign papers to the respective sections.

2. To arrange the scientific business of the general meetings, to suggest topics and arrange the programmes for the evening meetings.

3. To suggest to the Association the place and time of the next meeting.

4. To examine, and, if necessary, to exclude papers.

5. To suggest to the Association subjects for scientific reports and researches.

6. To appoint the Local Committee.

7. To have the general direction of publications.

8. To manage any other general business of the Association during the session, and during the interval between it and the next meeting.

9. In conjunction with four from each section, to be elected by the sections for the purpose, to make nominations of officers of the Association for the following meeting.

10. To nominate persons for admission to membership.

11. Before adjourning, to decide which papers, discussions, or other proceedings shall be published.

### SECTIONS.

RULE 7. The Association shall be divided into two Sections, and as many sub-Sections as may be necessary for the scientific business, the manner of division to be determined by the Standing Committee of the Association. The two Sections may meet as one.

### SECTIONAL OFFICERS AND COMMITTEES.

RULE 8. On the first assembling of the Section, the members shall elect upon open nomination a permanent chairman and secretary, also three other members to constitute with these officers a Sectional Committee.

The Section shall appoint, from day to day, a chairman to preside over its meetings.

RULE 9. It shall be the duty of the Sectional Committee

of each section, to arrange and direct the proceedings in their Section; to ascertain what communications are offered; to assign the order in which these communications shall appear, and the amount of time which each shall occupy.

The Sectional Committees may likewise recommend subjects for systematic investigation by members willing to undertake the researches, and to present their results at the next meeting.

The Sectional Committees may likewise recommend reports on particular topics and departments of science, to be drawn up as occasion permits, by competent persons, and presented at subsequent meetings.

REPORTS OF PROCEEDINGS.

RULE 10. Whenever practicable, the proceedings shall be reported by professional reporters or stenographers, whose reports are to be revised by the secretaries before they appear in print.

PAPERS AND COMMUNICATIONS.

RULE 11. No paper shall be placed in the programme, unless admitted by the Sectional Committee; nor shall any be read, unless an abstract of it has been previously presented to the Secretary of the Section, who shall furnish to the chairman the titles of papers of which abstracts have been received.

RULE 12. The author of any paper or communication shall be at liberty to retain his right of property therein, provided he declare such to be his wish before presenting it to the Association.

RULE 13. Copies of all communications, made either to the General Association or to the Sections, must be furnished by the authors; otherwise only the titles or abstracts shall appear in the published proceedings.

RULE 14. All papers, either at the general or in the Sectional meetings, shall be read, as far as practicable, in

the order in which they are entered upon the books of the Association; except that those which may be entered by a member of the Standing Committee of the Association shall be liable to postponement by the proper Sectional Committee.

RULE 15. If any communication be not ready at the assigned time, it shall be dropped to the bottom of the list, and shall not be entitled to take precedence of any subsequent communication.

RULE 16. No exchanges shall be made between members without authority of the respective Sectional Committees.

### GENERAL AND EVENING MEETINGS.

RULE 17. The Standing Committee shall appoint any general meeting which the objects and interests of the Association may call for, and the evenings shall, as a rule, be reserved for general meetings of the Association.

These general meetings may, when convened for that purpose, give their attention to any topics of science which would otherwise come before the Sections.

It shall be a part of the business of these general meetings to receive the Address of the President of the last meeting; to hear such reports on scientific subjects as, from their general importance and interests, the Standing Committee shall select; also to receive from the chairmen of the Sections abstracts of the proceedings of their respective Sections; and to listen to communications and lectures explanatory of new and important discoveries and researches in science, and new inventions and processes in the arts.

### ORDER OF PROCEEDINGS IN ORGANIZING A MEETING.

RULE 18. The Association shall be called to order by the President of the preceding meeting, and this officer having resigned the chair to the president elect, the general Secretary shall then report the number of papers relating to each department which have been registered, and the

Association consider the most eligible distribution into Sections, when it shall proceed to the election of the additional members of the Standing Committee in the manner before described; the meeting shall then adjourn, and the Standing Committee, having divided the Association into Sections as directed, shall allot to each its place of meeting for the Session. The Sections shall then organize by electing their officers and their representatives in the Nominating Committee and shall proceed to business.

### PERMANENT SECRETARY.

RULE 19. It shall be the duty of the Permanent Secretary to notify members who are in arrears, to provide the necessary stationery and suitable books for the list of members and titles of papers, minutes of the general and sectional meetings, and for other purposes indicated in the rules, and to execute such other duties as may be directed by the Standing Committee or by the Association.

The Permanent Secretary shall make a report annually to the Standing Committee, at its first meeting, to be laid before the Association, of the business of which he has had charge since its last meeting.

All members are particularly desired to forward to the Permanent Secretary, so as to be received before the day appointed for the Association to convene, complete titles of all the papers which they expect to present during its meeting, with an estimate of the time required for reading each, and such abstracts of their contents as may give a general idea of their nature.

Whenever the Permanent Secretary notices any error of fact or unnecessary repetition, or any other important defect in the papers communicated for publication in the proceedings of the Association, he is authorized to commit the same to the author, or to the proper sub-committee of the Standing Committee for correction.

LOCAL COMMITTEE.

RULE 20. The Local Committee shall be appointed from among members residing at or near the place of meeting for the ensuing year; and it shall be the duty of the Local Committee, assisted by the officers, to make arrangements and the necessary announcements for the meeting.

The Secretary of the Local Committee shall issue a circular in regard to the time and place of meetings, and other particulars, at least one month before each meeting.

SUBSCRIPTIONS.

RULE 21. The amount of the subscription, at each meeting, of each member of the Association shall be two dollars, and one dollar in addition shall entitle him to a copy of the proceedings of the annual meeting. These subscriptions shall be received by the Permanent Secretary, who shall pay them over, after the meeting, to the Treasurer.

No person shall be considered a member of the Association until the subscription for the meeting at which he is elected has been paid.

RULE 22. The names of all persons two years in arrears for annual dues shall be erased from the list of members; provided that two notices of indebtedness, at an interval of at least three months, shall have been previously given.

ACCOUNTS.

RULE 23. The accounts of the Association shall be audited annually, by auditors appointed at each meeting.

ALTERATIONS OF THE CONSTITUTION.

RULE 24. No article of this constitution shall be altered, or amended, or set aside, without the concurrence of three fourths of the members present, and unless notice of the proposed change shall have been given at the preceding annual meeting.

# RESOLUTIONS AND ENACTMENTS

OF A

# PERMANENT AND PROSPECTIVE CHARACTER,

PASSED PREVIOUS TO THE TENTH MEETING.

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*Resolved,* That a *manual* or *manuals of scientific observation and research,* especially adapted to the use of the American inquirer, comprising directions for properly observing phenomena in every department of physical science, and for making collections in natural history, etc., whether on land or at sea, is much needed at the present time; and that such a publication, placed in the hands of officers of the army and navy, would greatly tend to develop the natural resources of our extended country, and to the general advancement of science.

*Resolved,* That the American Association for the Advancement of Science cordially recommends the Smithsonian Institution to undertake the preparation of such a volume, under the editorial superintendence of its Secretary, to be published in its series of reports.

*Resolved,* That this Association will cordially coöperate in the production of such a manual or manuals, in whatever manner may be best adapted to secure the end in view.

(*Proceedings Second Meeting,* 1849, pp. 273, 351.)

*Resolved,* That a copy of the printed volume of Proceedings of the Meetings at Philadelphia, Cambridge, and New Haven be presented to the libraries of Harvard and Yale.

(*Proceedings Fourth Meeting,* 1850, p. 346.)

*Resolved*, That the Treasurer be requested to retain $300 of the funds in his hands, and belonging to the Association, for the purpose of paying the salary of the Permanent Secretary; said payment to be made at such time, and in such manner, as may be agreed upon by the Treasurer and Permanent Secretary.

*Resolved*, That copies of the Proceedings of the American Association be presented to the New York Lyceum and the Philadelphia Academy of Natural Sciences.

(*Proceedings Fourth Meeting*, 1850, pp. 390, 391.)

*Resolved*, That copies of the Proceedings of the American Association for the Advancement of Science be presented to the American Academy of Arts and Sciences, Boston; to the Boston Society of Natural History; to the New York Lyceum of Natural History; to the American Philosophical Society and to the Academy of Natural Sciences of Philadelphia; to the Smithsonian Institution; and to the Western Academy of Natural Sciences at Cincinnati.

(*Proceedings Fifth Meeting*, 1851, p. 249.)

*Resolved*, That the names of those only shall be entered in the list of members who shall have signified their acceptance.

(*Proceedings Seventh Meeting*, 1853.)

*Resolved*, That a sum not exceeding seventy-five dollars shall be paid to the Permanent Secretary, to defray the expenses necessary for attending each meeting of the Association.

(*Proceedings Seventh Meeting*, 1853.)

*Resolved*, That the following members be requested to report on the subjects respectively assigned to them, viz.:—

Prof. A. D. BACHE. *On Recent Additions to our Knowledge of the Theory of Tides.*

Prof. JOSEPH HENRY. *On Recent Additions to our Knowledge of the Laws of Atmospheric Electricity.*

Prof. JAMES HALL. *On Recent Additions to our Knowledge of the Paleozoic Rocks.*

Prof. J. L. SMITH. *On the Recent Progress of Micro-Chemistry.*

Prof. WOLCOTT GIBBS. *On the Recent Progress of Organic Chemistry.* (This Report was made at the Providence Meeting.)

Dr. JOSEPH LEIDY. *On the Remains of Fossil Reptiles and Mammals in North America.*

Prof. BENJAMIN PEIRCE. *On the Present State of the Theory of Planetary Perturbations.*

Dr. W. I. BURNET. *On Recent Advances in Anatomy and Physiology.*

Prof. J. D. DANA. *On the Geographical Distribution of the Lower Animals.*

Prof. LOUIS AGASSIZ. *On the History of our Knowledge of Alternation of Generation in Animals.*

Prof. S. S. HALDEMAN. *On the Present State of our Knowledge of Linguistic Ethnology.* (This Report was made at the Albany Meeting.)

Dr. B. A. GOULD, Jr. *On the Progress and Developments of the Electro-Chronographic Method of Observation.*

(*Proceedings Seventh Meeting*, 1853.)

# MEMBERS

OF THE

# AMERICAN ASSOCIATION

FOR THE

# ADVANCEMENT OF SCIENCE.

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NOTE.—Names of deceased members are marked with an asterisk (*); and those of members who, in 1840, formed the original "Association of American Geologists," are in small capitals. The figure at the end of each name refers to the meeting at which the election took place.

## A.

Abbott, Gorham D., New York [7].
Abert, Col. J. J., Washington, D. C. [1].
*Adams, Prof. C. B., Amherst, Massachusetts [1].
Agassiz, Prof. Louis, Cambridge, Massachusetts [1].
Alexander, Prof. Stephen, Princeton, New Jersey [1].
Allen, Prof. E. A. H., New Bedford, Massachusetts [6].
Allen, George N., Oberlin, Ohio [5].
Allen, John H., Oxford, Maryland [6].
Allen, Nathaniel T., West Newton, Massachusetts [10].
Allen R. L., M. D., Saratoga Springs, New York [10].
Allen, Zachariah, Esq., Providence [1].
Allston, R. F. W., Esq., Georgetown, South Carolina [3].
Allyn, Rev. Robert, E. Greenwich, Rhode Island [9].
Ames, Bernice D., Fort Edward, New York [10].
*Ames, M. P., Esq., Springfield, Massachusetts [1].

Amory, Jonathan, Jamaica Plains, Massachusetts [8].
Anderson, Pres. M. B., Rochester, New York [10].
Andrews, Alonzo, Lewiston, Maine [7].
Andrews, Dr. E. H., Charlotte, North Carolina [3].
Andrews, Prof. E. B., Marietta, Ohio [7].
Angell, Prof. James B., Providence [9].
Anthony, Charles H., Esq., Albany [6].
Anthony, Henry, Providence [9].
Anthony, J. G., Esq., Cincinnati, Ohio [1].
Appleton, Nathan, Esq., Boston [1].
Appleton, Thomas G., Boston [8].
Arden, Thomas B., Garrison's P. O., Putnam Co., New York [7].
Armour, A. H., Toronto, Canada [10].
Armsby, Prof. J. H., Albany [6].
Astrop, R. F., Crichton's Store, Burns Co., Virginia [7].
Austin, Samuel, Providence [9].

## B.

Bache, Prof. Alexander D., Washington, D. C. [1].
Bache, Dr. Franklin, Philadelphia [1].
Bacon, Dr. John, Jr., Boston [1].
Bacon, William, Richmond, Berkshire Co., Massachusetts [7].
Bagg, Moses M., Utica, New York [4].
*Bailey, Prof. J. W., West Point, New York [1].
Baird, Prof. S. F., Washington, D. C. [1].
Baldwin, F. H., Waverley, New York [10].
Barber, Edgar A., Albany, New York [10].
Barlow, Thomas, Canastota, New York [7].
Barnard, F. A. P., Oxford, Mississippi [7].
Barnes, Capt. James, Springfield, Massachusetts [5].
Barnston, Dr. James, Montreal, Canada [10].
Barratt, Dr. J. P., Barrattsville, South Carolina [3].
Barrows, George B., Fryeburg, Maine [7].
Bartlett, J. R., Providence [8].
Bartlett, Prof. W. H. C., West Point, New York [9].
Barton, Dr. E. H., New Orleans [9].
Bassnett, Thomas, Ottawa, Illinois [8].
Batchelder, J. M., Cambridge, Massachusetts [8].

Beadle, Dr. E. L., New York [1].
Beadle, E. R., Hartford, Connecticut [10].
Bean, Sidney A., Waukesha, Wisconsin [9].
Beck, Dr. C. F., Philadelphia [1].
*Beck, Prof. Lewis C., New Brunswick, New Jersey [1].
*Beck, Dr. T. Romeyn, Albany [1].
Bell, Samuel N., Manchester, New Hampshire [7].
Benedict, Erastus G., New York [10].
Benedict, F. N., Burlington, Vermont [1].
Benedict, Dr. N. B., New Orleans [10].
Bent, Silas, U. S. N., New York [10].
Bigelow, Artemas, Newark, New Jersey [9].
*Binney, Dr. Amos, Boston [1].
Binney, Amos, Esq., Boston [9].
*Binney, John, Esq., Boston [3].
Blackie, Dr. George S., Edinburgh, Scotland [10].
Blake, Eli W. C., New Haven, Connecticut [1].
Blake, J. R., Greensboro, Georgia [10].
Blake, William P., Esq., Washington, D. C. [2].
*Blanding, Dr. William, Rhode Island [1].
Blatchford, Dr. Thomas W., Troy, New York [6].
Blodget, Lorin, Washington, D. C. [7].
Bolta, James, Richmond, Virginia [10].
*Bomford, Col. George, Washington, D. C. [1].
Bond, George P., Esq., Cambridge, Massachusetts [2].
Bond, William C., Esq., Cambridge, Massachusetts [2].
Bonnycastle, Sir Charles, Montreal, Canada [1].
Borland, J. N., M. D., Boston [9].
Botta, Prof. Vincenzo, New York [9].
Bouve, Thomas T., Boston [1].
Bowditch, Henry J., M. D., Boston [2].
Boyden, Uriah A., Esq., Boston [2].
Boynton, John F., Esq., Syracuse, New York [4].
Bradford, George W., Homer, New York [10].
Brainerd, Prof. Jehu, Cleveland, Ohio [5].
Brant, James R., New York [9].
Breevort, J. Carson, Brooklyn, New York [1].
Brocklesby, Prof. John, Hartford, Connecticut [4].

Brooks, Rev. Charles, Boston [9].
Bross, William, Chicago, Illinois [7].
Brown, Andrew, Esq., Natchez, Mississippi [1].
Brown, John C., Esq., Providence [9].
Brown, Richard, Esq., Sydney, Cape Breton [1].
Brown, Prof. W. Leroy, Athens, Georgia [7].
Brunnow, Prof. F., Ann Arbor, Michigan [10].
Buchanan, Robert, Esq., Cincinnati, Ohio [2].
Buell, David, Jr., Troy, New York [6].
Bulkley, John W., Brooklyn, New York [10].
Bullard, Edward F., Waterford, New York [10].
*Burnett, Waldo I., Esq., Boston [1].
Burton, Dr. C. V. W., Lansingburg, New York [6].
Busher, James, Worcester, Massachusetts [9].
Butler, Thomas B., Norwalk, Connecticut [10].

C.

Cabell, Prof. James L., University of Virginia [6].
Campbell, John, New York [10].
Carey, H. C., Burlington, New Jersey [8].
Carley, S. T., Esq., Cincinnati, Ohio [5].
*Carpenter, Thornton, Camden, South Carolina [7].
*Carpenter, Dr. William M., New Orleans [1].
Carr, E. S., Albany [9].
Case, Hon. William, Cleveland, Ohio [6].
Caswell, Prof. Alexis, Providence [2].
Cavert, Michael P., Amsterdam, New York [10].
Chadbourne, Prof. P. A., Williamstown, Massachusetts [10].
Chamberlain, Frank, Albany [10].
Chandler, M. W. T., Philadelphia [8].
Channing, William F., Esq., Boston [2].
*Chapman, Dr. N., Philadelphia [1].
Chase, Rev. Benj., Natchez, Mississippi [7].
Chase, Prof. George I., Providence [1].
Chase, Theodore R., Cleveland, Ohio [7].
*Chase, Prof. S., Dartmouth, New Hampshire [2].
Chauveau, Pierre I. O., Montreal, Canada [10].
Chauvenet, Prof. William, Annapolis, Maryland [1].

Cherriman, J. B., Toronto, Canada [9].
Chesbrough, E. S., Chicago, Illinois [2].
Choate, Charles Francis, Cambridge, Massachusetts [7].
Church, Prof. A. E., West Point, New York [10].
Clapp, Dr. Asahel, New Albany, Indiana [1].
Clark, Alvin, Esq., Cambridgeport, Massachusetts [4].
Clark, Joseph, Esq., Cincinnati, Ohio [5].
Clark, Lester M., Canandaigua, New York [10].
Clark, Maj. M. Lewis, St. Louis, Missouri [5].
Clark, Prof. James, Georgetown, D. C. [8].
Clarke, Robert, Cincinnati, Ohio [7].
Cleaveland, Prof. C. H., Cincinnati, Ohio [9].
Clement, H. H., Providence [9].
*Cleveland, Dr. A. B., Cambridge, Massachusetts [2].
Clum, Henry A., New York [9].
Coakley, Prof. George W., St. James's College, Hagerstown, Maryland [5].
Coates, Dr. B. H., Philadelphia [1].
Coffin, Prof. James H., Easton, Pennsylvania [1].
Coffin, Prof. John H. C., Annapolis, Maryland [1].
Cogswell, Dr. Mason F., Albany [4].
*Cole, Thomas, Esq., Salem, Massachusetts [1].
*Coleman, Rev. Henry, Boston [1].
Collins, Dr. George L., Providence [9].
Colton, Willis S., New Haven, Connecticut [8].
Conant, Marshall, South Bridgewater, Massachusetts [7].
Congdon, Charles, Esq., New York [1].
Cook, Prof. George H., Albany [6].
Cooke, Robert L., Bloomfield, Essex Co., New Jersey [7].
Cooley, James E., New York [10].
Cooper, Dr. J. G., Orange, New Jersey [10].
Cooper, William, Hoboken, New Jersey [9].
Corning, Hon. Erastus, Albany [6].
Cottle, Thomas J., Woodstock, Upper Canada [10].
Couch, Lieut. Darius N., Washington, D. C. [8].
Couper, J. Hamilton, Esq., Darien, Georgia [1].
Crandall, Pardon S., Troy, New York [10].
Crosby, Alpheus, Hanover, New Hampshire [10].

Croswell, Edwin, Albany [6].
Cruikshank, James, Albany [10].
Curley, Prof. James, Georgetown, D. C. [8].

## D.

Dana, Prof. James D., New Haven, Connecticut [1].
Daniels, Edward, Ceresco, Wisconsin [7].
Dascomb, Prof. James, Oberlin, Ohio [7].
Davenport, Rev. James R., Albany [6].
Davidson, Robert, New Brunswick, New Jersey [10].
Davies, Charles, Fishkill Landing, New York [10].
Davis, James, Jr., Esq., Boston [1].
Davis, Prof. N. K., Marion, Alabama [9].
Dawson, Prof. J. W., Montreal, Canada [10].
Dayton, A. O., Esq., Washington, D. C. [4].
Dayton, Edwin A., Madrid, St. Lawrence Co., New York [7].
Dean, Prof. Amos, Albany [6].
Dean, Philotus, Alleghany City, Pennsylvania [7].
*Dearborn, Gen. H. A. S., Roxbury, Massachusetts [1].
*DeKay, Dr. James E., New York [1].
Delafield, Joseph, Esq., New York [1].
Delano, Joseph C., Esq., New Bedford, Massachusetts [5].
Delavan, Edward C., Albany [10].
Devol, Charles, Albany [10].
Dewey, Prof. Chester, Rochester, New York [1].
De Wolf, Prof. John, Bristol, Rhode Island [9].
Dexter, George, Albany [10].
Dexter, James, Albany [6].
Dickinson, John W., Westfield, Massachusetts [10].
Diehl, Rev. Israel S., Sacramento, California [10].
Dinwiddie, Robert, Esq., New York [1].
Dixwell, Epes S., Esq., Cambridge, Massachusetts [1].
Doremus, R. Ogden, New York [10].
Douglass, Prof. Silas H., Ann Arbor, Michigan [6].
Downes, John, Washington, D. C. [10].
*Ducatel, Dr. J. T., Baltimore [1].
Duffield, George, D. D., Detroit, Michigan [10].
Duncan, Lucius C., New Orleans [10].

Dunglison, Prof. Robley, Philadelphia [8].
Dwinelle, William H., New York [10].
Dyer, David, Albany [10].
Dyer, Elisha, Providence [9].

## E.

Easter, John D., Esq., Washington, D. C. [6].
Edmundson, Thomas, Baltimore [10].
Edwards, Richard, Salem, Massachusetts [10].
Elderhorst, Prof. William, Troy, New York [10].
Eliot, C. W., Cambridge, Massachusetts [8].
Elliott, Ezekiel B., Boston [10].
Elwyn, Dr. Alfred L., Philadelphia [1].
Ely, Charles Arthur, Esq., Elyria, Ohio [4].
Ely, Dr. J. W. C., Providence [9].
Emerson, George B., Esq., Boston [1].
EMMONS, Dr. EBENEZER, Albany [1].
Emory, Col. William H., U. S. A., Washington, D. C. [5].
Engelmann, Dr. George, St. Louis, Missouri [1].
Engstrom, A. B., Esq., Burlington, New Jersey [1].
Estes, Dr. D. C., Albany [10].
Eustis, Prof. H. L., Cambridge, Massachusetts [2].
Evans, Prof. John, M. D., Chicago, Illinois [5].
Everett, Hon. Edward, Boston [2].
Ewbank, Thomas, Washington, D. C. [8].
Ewing, Hon. Thomas, Lancaster, Ohio [5].

## F.

Fairchild, Prof. J. H., Oberlin, Ohio [5].
Fairfield, J. W., Hudson, New York [10].
Fairie, James, Bastross, Morehouse Parish, Louisiana [7].
Farmer, Moses G., Boston [9].
Fearing, Dr. E. P., Nantucket, Massachusetts [8].
Fellows, Joseph, Albany [10].
Ferris, Rev. Dr. Isaac, New York [6].
Fillmore, Millard, Buffalo, New York [7].
Fisher, Mark, Trenton, New Jersey [10].

Fisher, Dr. N. A., Norwich, Connecticut [9].
Fisher, Robert A., Providence [9].
Fisher, Thomas, Philadelphia [8].
Fisk, Prof. L. R., Ypsilanti, Michigan [10].
Fitch, Alexander, Esq., Carlisle, New York [1].
Fitch, O. H., Ashtabula, Ohio [7].
Foote, Elisha, Seneca Falls, New York [10].
Force, Col. Peter, Washington, D. C. [4].
Fosgate, Blanchard, M. D., Auburn, New York [7].
Foster, J. W., Esq., Monson, Massachusetts [1].
Foster, Prof. John, Schenectady, New York [1].
Fowle, William B., Esq., Boston [1].
*Fox, Rev. Charles, Grosse Isle, Michigan [7].
Francfort, Dr. E., Middletown, Connecticut [9].
Freeman, Dr. Samuel H., Albany [10].

## G.

Gale, L. D., Washington, D. C. [8].
Gardner, James S., Whitestown, New York [10].
Garrigue, Dr. S. S., Philadelphia [10].
Gavit, John E., Esq., Albany [1].
Gay, A. M., Charlestown, Massachusetts [10].
*Gay, Dr. Martin, Boston [1].
Geddings, Prof. E., Charleston, South Carolina [3].
Gibbes, Prof. L. R., Charleston, South Carolina [1].
Gibbes, Prof. Robert W., Columbia, South Carolina [1].
Gibbon, Dr. J. H., Charlotte, North Carolina [3].
Gibbs, Dr. Wolcott, New York [1].
Gifford, J. P. S., Albany [10].
Gillespie, W. M., Schenectady, New York [10].
Gilman, Daniel C., New Haven, Connecticut [10].
*Gilmor, Robert, Esq., Baltimore [1].
Gladstone, T. H., London [10].
Girard, Charles, Esq., Washington, D. C. [2].
Glück, Isidor, New York [10].
Glynn, Com. James, U. S. N., New Haven, Connecticut [1].
Gold, Theodore S., West Cornwall, Connecticut [4].
Goodwin, W. F., Concord, New Hampshire [10].

Gould, B. A., Esq., Boston [2].
Gould, Dr. B. A., Jr., Cambridge, Massachusetts [2].
Graham, George, Esq., Cincinnati, Ohio [5].
Graham, Col. James D., U. S. A., Washington, D. C. [1].
Gray, Prof. Asa, Cambridge, Massachusetts [1].
*Gray, Dr. James H., Springfield, Massachusetts [6].
Green, Horace, New York [10].
Green, Dr. John W., New York [9].
Green, Dr. Traill, Easton, Pennsylvania [1].
Greene, Dr. Benjamin D., Boston [1].
Greene, David B., New York [10].
Greene, Everett W., Madison, New Jersey [10].
Greene, Prof. B. Franklin, Troy, New York [1].
Greene, Samuel, Woonsocket, Rhode Island [9].
Greene, Prof. Samuel S., Providence [9].
Greene, Thomas A., New Bedford, Massachusetts [9].
Griffin, Prof. Nathaniel M., Williamstown, Massachusetts [10].
*Griffith, Dr. Robert E., Philadelphia [1].
Grinnan, A. G., Madison Court House, Virginia [7].
Groneweg, Lewis, Germantown, Ohio [7].
Grosvenor, A. C., Esq., Cincinnati, Ohio [5].
Grosvenor, Dr. William, Providence [9].
Gruvern, Julius, New Haven, Connecticut [10].
Guest, William E., Esq., Ogdensburg, New York [6].
Gulick, John T., Williamstown, Massachusetts [10].
Guyot, Prof. A., Princeton, New Jersey [1].

H.

Hackley, Prof. Charles W., New York [4].
Hague, John M., Esq., Newark, New Jersey [6].
Hague, William W., Esq., Newark, New Jersey [6].
Haines, William S., Providence [9].
Haldeman, Prof. S. S., Columbia, Pennsylvania [1].
Hale, Albert W., Albany [10].
*Hale, Dr. Enoch, Boston [1].
Hall, Archibald, Montreal, Canada [10].
HALL, Prof. JAMES, Albany [1].
Hall, Joel, Athens, Illinois [7].

Hall, N. K., Buffalo, New York [7].
Hallowell, Benjamin, Alexandria, Virginia [7].
Hamlin, A. C., Bangor, Maine [10].
Hammond, Ogden, Charleston, South Carolina [3].
Hance, Ebenezer, Morrisville, Bucks Co., Pennsylvania [7].
Handy, Isaac W. K., Portsmouth, Virginia [10].
Hardcastle, Edmund L. F., U. S. A., Washington, D. C. [7].
Harlan, Prof. Joseph G., Haverford, Pennsylvania [8].
*Harlan, Dr. Richard, Philadelphia [1].
Harrequi, Prof. José Salazar, Minerra, Mexico [10].
*Harris, Dr. Thaddeus W., Cambridge, Massachusetts [1].
*Hart, Simeon, Esq., Farmington, Connecticut [1].
Harte, R. E., Columbus, Ohio [7].
Harvey, Hon. Matthew, Concord, New Hampshire [1].
Harvey, Prof. William H., Trinity College, Dublin [3].
Hathaway, Charles, Delhi, New York [10].
Haupt, Herman, Esq., Philadelphia [3].
Haven, Samuel F., Worcester, Massachusetts [9].
*Hayden, Dr. H. H., Baltimore [1].
Hayward, James, Esq., Boston [1].
Hazard, Rowland, Peace Dale, Rhode Island [9].
Hedrick, Prof. B. S., Chapel Hill, North Carolina [8].
Heffron, Daniel S., Utica, New York [10].
Helme, W. H., Providence [9].
Henry, Prof. Joseph, Washington, D. C. [1].
Herbert, Alfred, Washington, D. C. [8].
Herrick, Edward C., Esq., New Haven, Connecticut [1].
Hicks, Levi I., Walworth, New York [10].
Hilgard, Julius E., Esq., Washington, D. C. [4].
Hilgard, Dr. T. C., Belleville, Illinois [8].
Hill, Nathaniel P., Providence, Rhode Island [10].
Hill, Nicholas, Jr., Albany [6].
Hill, S. W., Esq., Eagle Harbor, Lake Superior [6]
Hill, Rev. Thomas, Waltham, Massachusetts [3].
Hingston, Dr. W. P., Montreal, Canada [10].
HITCHCOCK, Pres. EDWARD, Amherst, Massachusetts [1].
Hitchcock, Edward, Jr., Amherst, Massachusetts [4].
Hodgson, W. B., Savannah, Georgia [10].

Holbrook, Dr. John E., Charleston, South Carolina [1].
Holland, Joseph B., Monson, Massachusetts [9].
Holton, J. F., New York [9].
Homans, Sheppard, New York [10].
Hopkins, J. A., Milwaukee, Wisconsin [8].
Hopkins, T. O., Williamsville, New York [10].
Hopkins, Prof. William, Lima, New York [5].
Hopkins, Prof. W. F., Annapolis, Maryland [7].
Horan, E. J., Quebec, Canada [10].
Horsford, Prof. E. N., Cambridge, Massachusetts [1].
Horton, C. V. R., Chaumont, New York [10].
*HORTON, Dr. WILLIAM, Craigville, Orange Co., New York [1].
Hough, Dr. Franklin B., Albany [4].
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Howell, Robert, Esq., Nichols, Tioga Co., New York [6].
Hoy, Philo R., M. D., Racine, Wisconsin [7].
Hoyt, J. W., Cincinnati, Ohio [8].
Hubbard, Prof. Oliver P., Hanover, New Hampshire [1].
Humphrey, S. Dwight, New York [6].
Hun, Dr. Thomas, Albany [4].
Hunt, George, Providence [9].
Hunt, Lieut. E. B., U. S. A., Newport, R. I. [2].
Hunt, Thomas S., Montreal, Canada [1].
Hyatt, James, New York [10].

## I.

Ives, Moses B., Providence [9].
Ives, Thomas P., Providence [10].

## J.

JACKSON, Dr. CHARLES T., Boston [1].
Jackson, Prof. Samuel, Philadelphia [1].
Jacobs, Prof. M., Gettysburgh, Pennsylvania [8].
James, Prof. Charles S., Lewisburg, Pennsylvania [10].
James, M. P., Esq., Cincinnati, Ohio [5].
James, John, Alton, Illinois [10].

Jenkins, Thornton A., U. S. N., Washington, D. C. [7].
Jenks, J. W. P., Esq., Middleborough, Massachusetts [2].
Jenner, Solomon, Esq., New York [4].
Jennings, N. R., New Orleans [4].
Jewett, Prof. C. C., Roxbury, Massachusetts [2].
*JOHNSON, Prof. W. R., Washington, D. C. [1].
Johnson, William C., Utica, New York [6].
Johnson, Prof. John, Middletown, Connecticut [1].
Jones, Lieut. Catesby Ap. R., U. S. N. [8].
Jones, Rev. George, U. S. N. [9].
Joslin, Benjamin F., M. D., New York [10].
Joy, Prof. C. A., Schenectady, New York [8].
Judd, Orange, Esq., New York [4].

## K.

Keely, Prof. G. W., Waterville, Maine [1].
Kelley, Edwin, M. D., Elyria, Ohio [7].
Kendall, David, Rochester, New York [8].
Kendall, Joshua, Meadville, Pennsylvania [10].
Kennedy, Alfred L., M. D., Philadelphia [7].
Kent, Edward N., New York [8].
Kerr, W. C., Cambridge, Massachusetts [10].
King, Hon. Mitchell, Charleston [3].
Kingsley, Prof. C., Meadville, Pennsylvania [6].
Kirkpatrick, James A., Philadelphia [7].
Kirkpatrick, John, Cleveland, Ohio [7].
Kirkwood, Daniel, Bloomington, Indiana [7].
Kirtland, Dr. J. P., Cleveland, Ohio [1].
Kitchell, Dr. William, Newark, New Jersey [6].
Kite, Thomas, Cincinnati, Ohio [5].
Kurtz, J. D., Bucksport, Maine [3].

## L.

Lane, Ebenezer, Chicago, Illinois [3].
Lansing, Hon. Gerritt Y., Albany, New York [6].
Lapham, Increase A., Esq., Milwaukee, Wisconsin [3].
*Lasel, Prof. Edward, Williamstown, Massachusetts [1].

Latham, Prof. Richard P., Richmond, Virginia [8].
Lauderdale, John V., Cleveland, Ohio [10].
Lawrence, George N., New York [7].
Lea, Isaac, Esq., Philadelphia [1].
Leavenworth, Dr. M. C., Waterbury, Connecticut [1].
Le Conte, Maj. John, Philadelphia [1].
Le Conte, Dr. John L., Philadelphia [1].
Leconte, Prof. John, Columbia, South Carolina [3].
Leconte, Dr. Joseph, Athens, Georgia [3].
*Lederer, Baron von, Washington, D. C. [1].
Lee, Capt. Thomas J., U. S. A., Washington, D. C. [5]
Lesley, J. P., Esq., Philadelphia [2].
Lesley, Joseph, Jr., Philadelphia [8].
Lesley, Dr. William W., Monticello, Missouri [8].
Lieber, Oscar M., Columbia, South Carolina [8].
*Lindsley, Rev. James H., Stafford, Connecticut [1].
Lindsley, Dr. J. B., Nashville, Tennessee [1].
Linklaen, Ledyard, Esq., Cazenovia, New York [1].
Livermore, Rev. A. A., New York [5].
Locke, Luther F., M. D., Nashua, New Hampshire [7].
Lockwood, Moses B., Providence [9].
Logan, Sir William E., F. R. S., Montreal, Canada.
Loomis, Prof. Elias, New York [1].
Loomis, Prof. J. R., Lewisburg, Pennsylvania [10].
Loomis, Charles L., Wilmington, Delaware [9].
Loomis, Silas L., Washington, D. C. [7].
Lovering, Prof. Joseph, Cambridge, Massachusetts [2].
Lusher, Robert M., New Orleans [10].
Lyman, Chester S., Esq., New Haven, Connecticut [4].
Lynch, Rev. Dr. P. N., Charleston [2].
Lyon, Hon. Caleb, Lyonsdale, New York [8].

## M.

McAlpine, William J., Esq., Albany [6].
McCall, Col. George A., Philadelphia [7].
McCall, John, Utica, New York [10].
McCay, Pres. C. F., Columbia, South Carolina [3].

McCoy, Prof. Amasa, Albany [10].
M'Conihe, Hon. Isaac, Troy, New York [4].
McCulloch, Prof. R. S., New York [1].
McDonald, Marshal, Lexington, Virginia [7].
McFarlan, Henry, Dover, New Jersey [8].
Machin, Thomas, Albany [10].
Maclean, Prof. George M., Pittsburgh, Pennsylvania [5].
Macomber, David O., Middletown, Connecticut [10].
McNaughton, Dr. James, Albany [4].
McNaughton, Peter, M. D., Albany [10].
Macrae, Lieut. Archibald, North Carolina [8].
McRae, John, Esq., Camden, South Carolina [3].
Mahan, Prof. D. H., West Point, New York [9].
Mallett, Prof. J. W., Tuscaloosa, Alabama [10].
Marcy, O., Wilbraham, Massachusetts [10].
*Marsh, Dexter, Esq., Greenfield, Massachusetts [1].
Marsh, James E., Roxbury, Massachusetts [10].
Mason, Owen, Providence [9].
Mason, R. C., Appleton, Wisconsin [9].
MATHER, WILLIAM W., Esq., Columbus, Ohio [1].
Mathiot, George, Washington, D. C. [8].
Maupin, Prof. S., Charlottesville, Virginia [10].
Mauran, Dr. J., Providence [2].
Maury, Lieut. M. F., Washington, D. C. [1].
Meads, Orlando, Albany [6].
Means, Prof. A., Oxford, Georgia [5].
Meech, L. W., Preston, Connecticut [8].
Meek, F. B., Esq., Albany [6].
Merrick, S. V., Esq., Philadelphia [1].
Millington, Prof. John, Oxford, Mississippi [1].
Mitchell, Prof. O. M., Cincinnati, Ohio [3].
Mitchell, Maria, Nantucket, Massachusetts [4].
Mitchell, Hon. William, Nantucket, Massachusetts [2].
Moore, George H., New York [8].
Morange, William D., Albany [10].
Mordecai, Alfred, U. S. A., Washington, D. C. [7].
Morgan, Lewis H., Rochester, New York [10].
Morris, Margaretta H., Germantown, Pennsylvania [4].

*Morton, Dr. S. G., Philadelphia [1].
Munger, George G., Rochester, New York [10].
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Munsell, Joel, Albany [6].

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Newberry, Dr. John S., Cleveland, Ohio [5].
Newcomb, Dr. Wesley, Albany [10].
Newton, Hubert A., Esq., New Haven, Connecticut [6].
Newton, John, Orange Hill, Washington Co., Florida [7].
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Nichols, Dr. James R., Haverhill, Massachusetts [7].
Nichols, Prof. John A., New York [10].
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Norton, Rev. Niram, Fredonia, New York [8].
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O'Leary, Prof. Charles, Emmetsburg, Maryland [10].
Oliver, James Edward, Lynn, Massachusetts [7].
*Olmsted, Alexander F., New Haven, Connecticut [4].
Olmsted, Charles H., Esq., E. Hartford, Connecticut [1].
Olmsted, Prof. D., New Haven, Connecticut [1].
*Olmsted, Denison, Jr., Esq., New Haven, Connecticut [1].
Olney, Stephen T., Providence [9].
Opdyke, George, New York [8].
Ordway, John M., Roxbury, Massachusetts [9].
Ormiston, Rev. William, Toronto, Canada [10].
Osborn, A., Esq., Albany, New York [1].
Osborn, H. S., Liberty, Bedford Co., Virginia [10].
Osgood, Rev. Samuel, D. D., New York [8].

Osten Sacken, Baron R. von, Washington, D. C. [10].
Otis, George A., Jr., Springfield, Massachusetts [10].

## P.

Painter, Minshall, Lima, Delaware Co., Pennsylvania [7].
Palmer, Charles H., Portage Lake, Michigan [6].
Parker, Hon. Amasa J., Albany [6].
Parker, Prof. William H., Middlebury, Vermont [10].
*Parkman, Dr. Samuel, Boston [1].
Parry, Dr. Charles C., Davenport, Iowa [6].
Parsons, Dr. Charles H., Providence [9].
Parsons, Dr. Usher, Providence [9].
Parvin, Theodore S., Muscatine, Iowa [7].
Peale, Titian R., Esq., Washington, D. C. [1].
Peck, Lieut. G. W., U. S. T. E. [9].
Peirce, Prof. Benjamin, Cambridge, Massachusetts [1].
Pendleton, A. G., U. S. N., Washington, D. C. [7].
Perkins, Prof. G. R., Utica, New York [1].
Perry, Com. M. C., New York [10].
Peters, Dr. C. H. F., Albany [9].
Phelps, Philip, Jr., Hastings, New York [10].
Phelps, S. L., U. S. N., Washington, D. C. [8].
Pickering, Dr. Charles, Boston [1].
Pierce, Prof. William M., Petersburg, Virginia [10].
Pigott, A. Snowden, Baltimore [10].
Pitcher, Dr. Zina, Detroit, Michigan [1].
Pitman, Benn, Cincinnati [10].
Plant, I. C., Esq., Macon, Georgia [3].
*Plumb, Dr. Ovid, Salisbury, Connecticut [9].
Porter, Prof. John A., New Haven, Connecticut [4].
Potter, Rev. Dr. H. B., Albany [6].
Pourtales, L. F., Esq., Washington, D. C. [1].
Powers, A. E., Esq., Lansingburg, New York [1].
Prentice, E. P., Esq., Albany [2].
Prescott, Dr. William, Concord, New Hampshire [1].
Priest, Rev. J. A., Homer, New York [10].
Prince, W. R., Flushing, Long Island [10].
Prout, H. A., M. D., St. Louis, Missouri [7].

Pruyn, J. V. L., Esq., Albany [1].
Pruyn, Robert H., Albany [10].
Putnam, F. W., Salem, Massachusetts [10].
Pybos, Benjamin, Tuscumbia, Alabama [7].

## R.

Randell, John, New York [8].
Rankin, Robert G., New York [10].
Ray, Dr. Isaac, Providence [9].
Redfield, John H., Esq., New York [1].
*Redfield, William C., Esq., New York [1].
Reid, D. B., London [10].
Renwick, Prof. James, New York [1].
Resor, Jacob, Cincinnati, Ohio [8].
Reuben, Levi, New York [10].
Rhees, William J., Washington, D. C. [8].
Rice, De Witt C., New York [7].
Rice, Henry, North Attleborough, Massachusetts [7].
Rice, W. H., Albany [10].
Richards, Rev. W. C., Providence [9].
Richmond, A. B., Meadville, Pennsylvania [8].
Riddell, Dr. John L., New Orleans [1].
Riddell, William P., New Orleans [7].
Ripley, Hezekiah W., Esq., Harlan, New York [6].
Ritchie, E. S., Boston [10].
Robb, Prof. James, M. D., Fredericton, New Brunswick [4].
Robertson, Thomas D., Rockford, Illinois [10].
Rockwell, Alfred P., New Haven, Connecticut [10].
Rockwell, John A., Norwich, Connecticut [10].
Rodman, William M., Providence [9].
*Rogers, Prof. James B., Philadelphia [1].
ROGERS, Prof. ROBERT E., Philadelphia [1].
Rogers, Prof. W. B., Boston [1].
Rogers, William F., Philadelphia [10].
Rood, Ogden N., New Haven, Connecticut [7].
Roome, Martin R., New York [10].
Ruggles, Prof. William, Washington, D. C. [8].
Runkle, J. D., Esq., Cambridge, Massachusetts [2].

## S.

Safford, Prof. J. M., Lebanon, Tennessee [6].
Sager, Prof. Abraham, Ann Arbor, Michigan [6].
Sanford, R. K., Riga, New York [7].
Sargent, Rufus, Auburn, New York [10].
Savage, Thomas S., Pass Christian, Mississippi [10].
Saville, Henry M., Syracuse, New York [10].
Saxton, Joseph D., Esq., Washington, D. C. [1].
Scarborough, Rev. George, Owensburg, Kentucky [2].
Schaeffer, Prof. George C., Washington, D. C. [1].
Schank, Dr. J. Stilwell, Princeton, New Jersey [4].
Schnee, Alexander, Madison, Wisconsin [10].
Schoolcraft, Henry R., Washington, D. C. [7].
Schott, Arthur C. V., Washington, D. C. [8].
Schott, Charles A., Washington, D. C. [8].
Selden, George M., Esq., Troy, New York [6].
Seropyan, Christopher, New Haven, Connecticut [10].
Sessions, Rev. John, Albany [6].
Sestini, Prof. Benedict, Georgetown, D. C. [8].
Seward, Hon. William H., Auburn, New York [1].
Shaefer, P. W., Pottsville, Pennsylvania [4].
Shaffer, David H., Cincinnati, Ohio [7].
Shane, J. D., Lexington, Kentucky [7].
Shaw, Edward, Washington, D. C. [9].
Sheldon, D. H., Racine, Wisconsin [10].
Shepard, Prof. C. U., New Haven, Connecticut [4].
Shippen, William, Washington, D. C. [8].
Shumard, B. F., M. D., St. Louis, Missouri [7].
Sias, Solomon, Fort Edwards, New York [10].
Sill, Hon. Elisha, Cuyhaoga Falls, Ohio [6].
Silliman, Prof. Benjamin, New Haven, Connecticut [1].
Silliman, Prof. Benjamin, Jr., New Haven, Connecticut [1].
Skilton, Dr. Avery J., Troy, New York [6].
Skinner, George W., M. D., Little Falls, New York [10].
Smallwood, Charles, M. D., St. Martin, Isle Jesus, Canada East [7].
Smith, Prof. Augustus W., Middletown, Connecticut [4].
Smith, Capt. E. R., U. S. A. [8].
Smith, Prof. Francis H., Charlottesville, Virginia [9].

Smith, George, Upper Darby, Delaware Co., Pennsylvania [7].
Smith, James Y., Providence [9].
Smith, J. Bryant, M. D., New York [7].
Smith, Prof. J. Lawrence, Louisville [1].
Smith, Dr. Lyndon A., Newark, New Jersey [9].
*Smith, J. V., Esq., Cincinnati, Ohio [5].
Smith, Metcalf J., M'Granville, N. Y. [10].
Smith, Sanderson, New York [9].
Snell, Prof. Eben S., Amherst, Massachusetts [2].
Snow, Charles B., Washington, D. C. [8].
Snow, Edwin M., M. D., Providence [9].
Sparks, Jared, Cambridge, Massachusetts [2].
Spear, C. V., Pittsfield, Massachusetts [10].
Spencer, Thomas, Philadelphia [8].
Sprague, Charles Hill, Malden, Massachusetts [7].
Stanard, Benjamin A., Esq., Cleveland, Ohio [6].
Starr, William, Ceresco, Wisconsin [10].
Stearns, Eben S., Albany [10].
Stearns, Josiah A., Boston [10].
Stebbins, Rev. Rufus P., Cambridge, Massachusetts [2].
Steele, Samuel, Albany [10].
Steiner, Dr. Lewis H., Baltimore, Maryland [7].
Stetson, Charles, Cincinnati, Ohio [4].
Stevens, Prof. M. C., Richmond, Indiana [9].
Stevens, Robert P., M. D., Ceres, Alleghany Co., New York [7].
Stewart, Prof. William M., Clarksville, Tennessee [7].
Stillman, Dr. C. H., Plainfield, New Jersey [8].
Stillman, Dr. J. D. B., New York [8].
Stillman, Thomas B., New York [8].
Stone, Rev. Edwin M., Providence [9].
Storer, Dr. D. H., Boston [1].
Street, Alfred B., Albany [10].
Sturtevant, Pres. J. M., Jacksonville, Illinois [10].
Suckley, Dr. George, U. S. A. [9].
Sullivant, William S., Columbus, Ohio [7].
Sumner, George, Boston [8].
Sutherland, Prof. William, Montreal, Canada [6].
Swallow, G. C., Columbia, Missouri [10].

Swan, Gen. Lansing B., Rochester, New York [8].
Sweeney, Peter, Buffalo, New York [10].
Swinburne, John, Albany [6].

## T.

Tabor, Azor, Albany [6].
Talcott, Andrew, Cincinnati, Ohio [7].
*Tallmadge, Hon. James, New York [1].
Tappan, Chancellor H. P., Ann Arbor, Michigan [10].
Tatlock, Prof. John, Williamstown, Massachusetts [10].
Tatum, Joel H., Baltimore, Maryland [10].
Taylor, George W., Albany [10].
Taylor, Dr. Julius S., Carrolton, Montgomery Co., Ohio [1].
Taylor, Morse K., M. D., Galesburg, Knox Co., Illinois [7].
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Tefft, Thomas A., New York [9].
*Teschemacher, J. E., Esq., Boston [1].
Tevis, Robert C., Esq., Shelbyville, Kentucky [5].
Thomas, William A., Irvington, N. Y. [10].
Thomas, Prof. W. H. B., Philadelphia [9].
Thompson, Dr. Alexander, Aurora, New York [6].
Thompson, Aaron R., New York [1].
Thompson, John A., M. D., Cayuga, New York [10].
Thompson, Dr. J. W., Wilmington, Delaware [9].
Thompson, John Edgar, Esq., Philadelphia [1].
*Thompson, Rev. Z., Burlington, Vermont [1].
Thorn, James, M. D., Troy, New York [10].
Thurber, George, Esq., New York [1].
Thurber, Isaac, Providence [9].
Tobey, Dr. Samuel B., Providence [9].
Torrey, Dr. John, New York [1].
Torrey, Prof. Joseph, Burlington, Vermont [2].
Totten, Gen. J. G., U. S. A., Washington, D. C. [1].
Town, Salem, Aurora, New York [7].
Townsend, Hon. Franklin, Albany [4].
Townsend, Dr. Howard, Albany [10].
*Townsend, John K., Esq., Philadelphia [1].
Townsend, Robert, Albany [9].

*Troost, Dr. Gerard, Nashville, Tennessee [1].
Trowbridge, Prof. W. P., Ann Arbor, Michigan [10].
Truesdell, Samuel, New York [10].
Trumbull, James H., Esq., Hartford, Connecticut [4].
*Tuomey, Prof. M., Tuscaloosa, Alabama [1].
Turnbull Lawrence, Philadelphia [10].
Turner, William W., Washington, D. C. [7].
Tuthill, Franklin, M. D., New York [8].
*Tyler, Rev. Edward R., New Haven, Connecticut [1].
Tyler, Ranson H., Fulton, New York [10].

## V.

Vail, Prof. Hugh, Haverford, Pennsylvania [8].
Vancleve, John W., Dayton, Ohio [1].
Van Duzee, William S., M. D., Buffalo, New York [7].
Van Derpool, S. Oakley, Albany, New York [9].
Van Pelt, Wm., M. D., Williamsville, Erie Co., New York [7].
*Vanuxem, Lardner, Esq., Bristol, Pennsylvania [1].
Van Vleck, J. M., Middletown, Connecticut [9].
Vaughan, Daniel, Esq., Cincinnati, Ohio [5].
Vaux, William S., Esq., Philadelphia [1].
Verreau, H. A. B., Montreal, Canada [10].

## W.

Wadsworth, James S., Esq., Genesee, New York [2].
Wagner, Tobias, Philadelphia [9].
Walker, Rev. Jas. B., Mansfield, Ohio [7].
Walker, Joseph, Oxford, New York [10].
*Walker, Sears C., Esq., Washington, D. C. [1].
*Walker, Hon. Timothy, Cincinnati, Ohio [4].
Walling, Henry F., Providence [9].
Walworth, Reuben H., Saratoga, New York [10].
Warder, Dr. J. A., Cincinnati, Ohio [4].
*Warren, Dr. John C., Boston [1].
Wayland, Dr. Francis P., Providence [9].
Wayne, Rev. Benjamin, New Orleans [10].
Webber, Dr. Samuel, Charlestown, New Hampshire [1].
*Webster, H. B., Esq., Albany [1].

*Webster, Dr. J. W., Cambridge, Massachusetts [1].
*Webster, M. H., Esq., Albany [1].
Webster, Nathan B., Portsmouth, Virginia [7].
Webster, William F., Providence [9].
Weed, Monroe, Esq., Wyoming, New York [6].
Weinland, D. F., Cambridge, Massachusetts [10].
Welch, John, Newark, New Jersey [10].
Wells, David A., New York [2].
Wells, Dr. Thomas, New Haven, Connecticut [4].
Wescott, Rev. Isaac, New York [8].
West, Charles E., Esq., Buffalo, New York [1].
Wetherell, Prof. L., Legrange, Kentucky [2].
Weyman, G. W., Esq., Pittsburgh, Pennsylvania [6].
Wheatland, Dr. Henry, Salem, Massachusetts [1].
Wheatley, Charles M., New York [1].
Whipple, J. E., Lansingburg, New York [10].
Whipple, W., Adrian, Michigan [7].
Whitcomb, Joseph M., Salem, New York [10].
White, Aaron, Cazenovia, New York [10].
White, Charles, Crawfordsville, Indiana [10].
White, Horace, Chicago, Illinois [10].
Whitney, Asa, Esq., Philadelphia [1].
Whitney, J. D., Esq., Northampton, Massachusetts [1].
Whittlesey, Charles, Cleveland, Ohio [1].
Wilder, Alexander, Albany [10].
Wilder, L., Esq., Hoosick Falls, New York [1].
Wilkes, Capt. Charles, U. S. N., Washington, D. C. [1].
Willard, Samuel, Lima, New York [10].
Williams, Dr. Abraham V., New York [9].
Williams, Prof. L. D., Meadville, Pennsylvania [6].
Williams, Dr. P. O., Watertown, St. Lawrence Co., N. Y. [6].
Williams, Samuel Wells, Canton, China [10].
Williams, W. F., Mosul, Turkey [10].
Wills, Frank, New York [9].
Wilson, Prof. Daniel, Toronto, Canada [10].
Winchell, Prof. Alexander, Ann Arbor, Michigan [3].
Winlock, Prof. Joseph, Cambridge, Massachusetts [5].
Winslow, John F., Troy, New York [10].

Winslow, C. F., Troy, New York [10].
Woodbridge, George A., Auburndale, Massachusetts [10].
*Woodbury, Hon. L., Portsmouth, New Hampshire [1].
Woolworth, Hon. S. B., Albany [10].
Worcester, Dr. Joseph E., Cambridge, Massachusetts [2].
Worthen, A. H., Warsaw, Illinois [10].
Wright, Charles, Wethersfield, Connecticut [10].
Wright, Chauncey, Cambridge, Massachusetts [9].
*Wright, Dr. John, Troy, New York [1].
Wurtz, Henry, Trenton, New Jersey [10].
Wyman, Prof. Jeffries, Cambridge, Massachusetts [10].
Wynne, Dr. James, Baltimore [8].
Wynne, Thomas H., Richmond, Virginia [8].

## Y.

Yarnell, Prof. M., U. S. A. [8].
Youmans, E. L., Esq., Saratoga Springs, New York [6].
Young, Prof. Ira, Hanover, New Hampshire [7].

The above list contains seven hundred and eighty-four names, of which sixty-two are of deceased members.

# MEMBERS ELECTED AT THE ALBANY MEETING.*

Allen, Jerome, Dubuque, Iowa.
Allen, Nathaniel T., West Newton, Mass.
Allen, R. L., Saratoga Springs, N. Y.
Ames, Bernice D., Fort Edward, N. Y.
Anderson, M. B., Rochester, N. Y.
Armour, A. H., Toronto, Canada.
Baldwin, F. H., Waverley, N. Y.
Barber, Edgar A., Albany.
*Barnston, Dr. James, Montreal, Can.
Beadle, E. R., Hartford, Conn.
Benedict, Erastus C., New York.
*Benedict, Dr. N. B., New Orleans.
Bennett, Joseph, Albany.
Bent, Silas, U. S. N., New York.
Binkerd, F. S., Germantown, Ohio.
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Blake, J. R., Greensboro', Ga.
Bolton, James, Richmond, Va.
Bradford, G. W., Homer, N. Y.
*Brünnow, F., Ann Arbor, Mich.
Bulkley, John W., Brooklyn, N. Y.
Bullard, Edward F., Waterford, N. Y.
Butler, Thos. B., Norwalk, Conn.
Cameron, Daniel, Johnstown, N. Y.
Campbell, John, New York.
Cavert, M. P., Amsterdam, N. Y.
*Chadbourne, P. A., Williamstown, Mass.
Chamberlain, Frank, Albany.
*Chauveau, Pierre J. O., Montreal, Canada.
*Church, A. E., West Point, N. Y.
Clark, Lester M., Canandaigua, N. Y.
Cole, Seth B., Albany.
Comfort, H. F., Middletown, Conn.
Conger, A. B., Haverstown, N. Y.
Cooley, J. E., New York.
*Cooper, Dr. J. G., Orange, N. J.
Cottle, T. J., Woodstock, Canada.
Cox, Samuel H., New York.
Crandall, Pardon S., Troy, N. Y.
Crosby, Alpheus, Hanover, N. H.
Cruikshank, James, Albany.
Dakins, Francis E., Albany.
Davidson, Robert, New Brunswick, N. J.
*Davies, Charles, Fishkill Landing, N. Y.
Dawson, J. W., Montreal, Canada.
Delavan, Edward C., Albany.
Devol, Charles, Albany.
Dexter, George, Albany.
Dickinson, John W., Westfield, Mass.
*Diehl, Israel, Sacramento, Cal.
Doremus, R., Ogden, N. Y.
Downes, John, Washington, D. C.
Duffield, George, Detroit, Mich.
Duncan, Lucius C., New Orleans.
Dwinelle, William H., New York.
Dyer, David, Albany.
Edmundson, Thomas, Baltimore.
Edwards, Richard, Salem, Mass.
Elderhorst, William, Troy, N. Y.
Elliot, Ezekiel B., Boston.
Estes, D. C., Albany.
Fairfield, J. W., Hudson, N. Y.
Fellows, Joseph, Albany.
Field, Roswell, Greenfield, Mass.
Fisher, Mark, Trenton, N. J.
*Fisk, L. R., Ypsilanti, Mich.
Flanagan, J., Montreal, Canada.
Flint, Lyman D., Concord, N. H.
Foote, Elisha, Seneca Falls, N. Y.
Fowler, Asa, Concord, N. H.
Freeman, Samuel H., Albany.
Fristoe, E. P., Washington, D. C.
Frothingham, Washington, Albany.
Gardner, James S., Whitestown, N. Y.
*Garrigues, Dr. S. S., Philadelphia.

* Those marked with an asterisk paid the assessment, and signed the Constitution without being formally elected.

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Gifford, J. P. S., Albany.
Gillespie, W. M., Schenectady, N. Y.
Gilman, D. C., New Haven, Conn.
*Gladstone, T. H., London, Eng.
Glück, Isidor, New York.
Goodrich, Charles S., New York.
Goodwin, William F., Concord, N. H.
Green, Everett W., Madison, N. J.
Green, Horace, New York.
Greene, David B., New York.
Griffen, N. H., Williamstown, Mass.
Gruvern, Julius, New Haven, Conn.
*Gulick, John T., Williamstown, Mass.
Hadley, Amos, Concord, N. H.
Hale, Albert W., Albany.
Hall, Archibald, Montreal, Canada.
Ham, L. J., Williamsville, N. Y.
Hamlin, Augustus C., Bangor, Me.
Handy, Isaac W. K., Portsmouth, Va.
Harrequi, Jose Salazar, Minerra, Mexico.
Hathaway, Charles, Delhi, N. Y.
Headley, William S., Albany.
Heffron, Daniel S., Utica, N. Y.
Hext, G., Oxford, England.
Hicks, Levi I., Walworth, N. Y.
Hill, Nathaniel P., Providence.
Hingston, W. P., Montreal, Canada.
Hodgson, W. B., Savannah, Geo.
Homans, Sheppard, New York.
Hopkins, James G., Ogdensburg, N. Y.
Hopkins, T. O., Williamsville, N. Y.
Horan, E. J., Quebec, Canada.
Horton, C. V. R., Chaumont, N. Y.
Hungerford, Edward, Wolcottville, Ct.
Hyatt, James, New York.
Ingham, Albert C., Madison, Wis.
Ives, Thomas Pointer, Providence.
*James, Charles S., Lewisburg, Penn.
James, John, Alton, Ill.
Jennings, Needler, New Orleans.
Johnson, B. P., Albany.
Johnston, Christopher, Baltimore, Md.
Jones, Thomas Walter, Montreal, Can.
Joslin, Benjamin F., New York.
Kendall, Joshua, Meadville, Penn.
Kerr, W. C., Cambridge, Mass.
Lauderdale, John V., Cleveland, Ohio.
Lieber, Francis, Columbia, S. C.
*Loomis, J. R., Louisburg, Penn.
Lusher, Robert M., New Orleans.
*Machin, Thomas, Albany, N. Y.
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McCoy, Amasa, Albany.
McMahon, Matthew, Albany.
McNaughton, Peter, Albany.
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Mitchell, Henry, Nantucket, Mass.
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Morse, M. L., Dover, N. H.
Munger, George G., Rochester, N. Y.
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Mussey, D., Albany.
*Newcomb, Wesley, Albany.
*Nichols, John A., New York.
Noble, Capt. London, England.
O'Callaghan, E. B., Albany.
*O'Leary, Charles, Emmetsburg, Md.
*Ormiston, William, Toronto, Canada.
Ormond, J. J., Tuscaloosa, Ala.
Osborn, H. S., Liberty, Va.
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Pitman, Benn, Cincinnati, Ohio.
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Porter, Samuel D., Rochester, N. Y.
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Rockwell, Alfred P., New Haven, Conn.
Rockwell, John A., Norwich, Conn.
Rogers, William F., Philadelphia.
Roome, Martin R., New York.
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Sanger, W. W., Albany.
Sargent, Rufus, Auburn, N. Y.
*Savage, Thomas S., Pass Christian, Miss.
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Sclater, Philip Lutley, Oxford, Eng.
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Sheldon, D. S., Davenport, Iowa.
Sias, Solomon, Fort Edward, N. Y.
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Smith, E. Peshine, Rochester, N. Y.

Smith, Metcalf J., M'Granville, N. Y.
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Sweeney, Peter, Buffalo, N. Y.
*Tappan, H. P., Ann Arbor, Mich.
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Townsend, Howard, Albany.
Treadwell, O. W., Rockville, Md.
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Vail, S. M., Concord N. H.
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Weinland, D. F., Cambridge, Mass.
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Weyde, Vander, New York.
Whipple, A. B., Nantucket, Mass.
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White, Aaron, Cazenovia, N. Y.
White, Charles, Crawfordsville, Ind.
White, Horace, Chicago, Ill.
Wilder, Alexander, Albany.
Willard, Samuel D., Lima, N. Y.
Williams, Samuel Wells, Canton, China.
Williams, W. F., Mosul, Turkey.
Wilson, Daniel, Toronto, Canada.
Winslow, C. F., Troy, N. Y.
Winslow, John F., Troy, N. Y.
Wood, William, Portland, Maine.
Woodbridge, George A., Auburndale, Mass.
Woolworth, S. B., Albany.
Worthen, A. H., Warsaw, Ill.
Wright, Charles, Wethersfield, Conn.
Wurtz, Henry, Trenton, N. J.
Wyman, Jeffries, Cambridge, Mass.
Zimmerman, Reuben, Alexander, Va.

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The following signed the Constitution, but were not formally elected and did not pay.

Beumard, Daniel, Chicago, Ill.
Forsyth, James, Troy, N. Y.
Homes, H. A., Albany, (State Library).
Hooper, C. Van Vorst, New York.
Lane, D., Troy, N. Y.
MacNair, John, New Orleans.
Mayhew, D. P., Ypsilanti, Mich.
Mütter, Thomas D., Philadelphia.
Sanders, J. Milton, Cincinnati.
Sprague, Joseph W., Rochester, N. Y.

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The following paid, but were not formally chosen, and did not sign the Constitution.

Army, W. F., Chicago, Ill.
Freeman, L. H., Albany.
McClure, A.
Paine, D. D.
Pendleson, E. B.
Wilson, J. Q.
Thompson, Robert.
Wendell, Dr. H., Albany.

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# REPORT

## ON THE PRESENT STATE OF OUR KNOWLEDGE

OF

## LINGUISTIC ETHNOLOGY.

By S. S. HALDEMAN, Columbia, Pa.

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This Report will be restricted to the portion of the subject pertaining to speech,—a portion which, although less extensive than the grammatical, lexicographical, or etymological portions of language, has not attracted proper attention until a recent period. This neglect is due to the difficulty of the subject, of which a constant example is at hand in the difficulty experienced in pronouncing foreign languages properly, even when they belong to the same stock, as Persian, German, Belgian, and English. The difficulty of pronouncing, appreciating, locating, explaining, and writing down the various phases of speech is so great, and there are so many sources of error, that we must be more cautious in accepting statements here, than in other sciences of observation, few having as much education in this branch as would be required to make a chemist or a musician; or to enable a singer to write down a song properly, even in a notation of his own invention. We cannot even trust an observer who claims for himself a good ear. The English lexicographer, Knowles, makes such a claim, and by his analysis proves that he does not possess the power to discriminate sounds; as in the case of *ye* and *woo*, which he considers equivalent to the repetitions *e-e* and *oo-oo*. The re-

porter is willing that the objections which he makes to the results of others should be urged against his own; and that his assertions should be received with as much caution as those of any observer, having at various times held views which further research proved to be untenable.

Spanish grammarians emphatically deny that their *b* ever partakes of the power of English and Spanish *v*. They claim both *b* and *v*, and assert that *v* (like *f*) is made by the application of the lower lip to the upper teeth, and that their *b* is never made thus, the lips alone being concerned in its production, so that it is impossible that it can be anything else than a genuine *b*. The facts are as here given, but the inference is false. The Spanish *b* between vowels, the German *w*, and, according to E. A. Sophocles, the Ellenic* β, differ from English *v* in being formed with the lips alone. It is therefore an aspirate of *b* (ʻ*B*) as the Greek φ is an aspirate of *p*, which *f* is not. This is an important point in ethnology, which few attend to. Doctor Lepsius does not allude to it, nor to the very distinct Russian vowel bl, in his recently published Standard Alphabet. Authors continually confound English labiodental *v* with German labial *w*, and in giving an account of the languages they investigate, they cannot be trusted upon this point; so that we have yet to learn which of the two sounds is present in certain languages, the phonology of which is apparently treated with great fulness. Judging from a partial investigation, the Russian 'B' has the power of English and French labio-dental *v*.

Some writers (as Le Brethon and Marsden), in comparing the French and English vowels, refer â to that in *fall*, and é to

* *Modern Greek* is an awkward expression, and *Romaic* is incorrect, and as the language has lost *h*, *Hellenic* has become *Ellenic*. The word *Anglo-Saxon* is equally awkward, and degenerates into "*Saxon*," — a name which should be restricted to *Plattdeutsch* in its modern and ancient or old Saxon form. The change of languages involves a change of pronunciation, as in the German *klar*, which closes to *clair* in French, and still farther to *clear* in English; so the language of Anglia and the Angles was *Anglish*, and passed through *Englísh*, with *e* in *met*, to the modern *Inglish*, with the vowel in *fit*.

that in *end;* whilst others (Picot, Bolmar, &c.) refer â to the English vowel in *arm*, and é to that in *fate*. Duponceau, in 1817 (Am. Phil. Trans. I. 229), refers the English vowel in *fat* to the French vowel in *terre*, *père*, an error which Germans commonly make. In the alphabet of Lepsius, *fat* would be written fĕ̱t, and the French *mère* mē̱r. Duponceau seems to have been the first to show that the initial vowel of the English diphthongs in *aisle* or *isle*, and *owl*, is not that in *arm*, but the French â, which is made with a narrower aperture than *a* in *arm* requires, and with a slight tendency towards *awe*. The same author gives as the components of English *u* in *usage*, the vowels of *eel* and *ooze*, — an error which is retained by most English authors, very few of whom know what a diphthong is.

Every vowel added to a word forms an additional syllable, and as English *u* is a monosyllable, one of its elements is a consonant; namely, the initial when it is pronounced *you*, and the final when, as is sometimes the case, it is a diphthong pronounced like the Welsh *iw* and Belgian *iew*, with the vowel of *it* (German *hitzig*) and *w* as a consonant in *now*, or German *u* in *haus*. Similarly, the final element of *clo-y* is a consonant, and of *claw-y* a vowel.* German and French writers seem not to be aware of the nature of diphthongs, and in Latin-English grammars they are described as vowels.† In most ethnic alphabets, including that of Lepsius, the last element of the diphthongs is represented by a vowel character, — a fundamental error founded upon the crude analysis of the ancients.‡ The term *diphthong* is itself almost useless, because,

* Hald. Latin Pronunciation, §§ 109, 111. Latham's English Language, 1841, p. 108, § 68.

† Andrews and Stoddard consider the vowels of *fall* and *feel* diphthongs, because they pronounce the Latin LAVS and AETAS with them. They say that "two *vowels* in immediate succession in the same syllable" (including UO, UA!) "are *called* a diphthong. Yet if AETAS is read with but four elements instead of five (the *a* in *arm* being omitted), the word does not contain "two vowels in immediate succession."

‡ Dr. Lepsius assigns (Standard Alphabet, p. 41) to the Latin *diphthong* OE (*oi* in *going*, when pronounced as a monosyllable) the power of the German *vowel* ö, and'

as the first element is already a vowel, the peculiarity lies in the second coalescing with the first, (an impossibility with a second and subsequent vowel,) whence it may be called a *coalescent*, meaning by this term those consonants that approximate as nearly as possible to the vowels.

In a French work on Russian, the twenty-ninth Russian letter, b, is explained by comparing it with the French "e mute," whilst the twenty-seventh letter is said to have no sound, but to indicate that the preceding consonant is to be pronounced with force, and as if it were doubled. This gives a very incorrect view of these letters. For example, the Russian word for *five* is a monosyllable with the short *a* in *art*, which might be represented pjatj in Latin or German letters, and pyaty in English letters, the final *y* being the Russian (b), and the modified y-sound following *l* in the French "ll mouillée." This addition to consonants is so common in Russian, that its absence is marked by the *yerr*, as in the word o-ke-án *ocean*, which is written with the final *yerr*. The allusion to doubled letters might cause Russian to be associated with Arabic, Latin, and Italian, which are among the few languages which have doubled or geminate elements, as in the Italian "Giovanni," *John*, in which each *n* is as distinctly sounded as in the English words *one name*.

Arabic has such doubled consonant sounds; yet it would be wrong to consider the sixteenth Arabic letter *tta* such a gemination on the authority of Richardson, who describes it (Grammar, p. 9) as "double *t*, or *t* with a slight aspiration," a description which is void of meaning, the reader being unable to tell whether the conjunction is copulative or disjunctive, and consequently whether the latter member of the sentence is explanatory of the former. Brown (Journey to Dar Fûr) assigns to the Dar Runga, words like *tta* water, *mmi* wo-

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ignoring the Latin nasal vowels, writes *kọlum* for COELUM. The dots are placed below ö to afford room above for accent marks, yet nasal vowels are indicated by (˜) above, which may call for vowel characters surmounted with the three signs (˜ ˘ ´). Thus the French word *sans* (sā̧) is long, and *cent* (să̧) is short.

man, *ddéta* mountain, *wwi* wind, *ggó* reprimanding; but as he gives no explanation of his notation, these are doubtful examples of geminate consonants.

Many English people fancy that they have double consonants, because they spell certain words (e. g. all, well, off, lesson, back, annex, allude) with double characters. This practice is in use to indicate a short preceding vowel, and when an Englishman writes a Latin Grammar, he is apt to believe and assert that syllables which are long "by position" are really short, but are "counted" or "considered" long, by a "mechanical rule"; whereas, the doubled consonants heard in Italian show that such syllables are really long, because it requires more time to pronounce two elements than one.* Similarly, Latin diphthongs are long, not by an arbitrary rule, but because the two elements of AV, AE, OE, &c. require more time than A and O alone.

*The nasal vowels* of but few foreign languages are properly understood, and the ignorance of writers whose vernacular does not contain them is frequently apparent. The error here is sometimes so great, as to cause a confusion between vowel and consonant, as in mistaking the nasal vowel of the French *fin* for the English and German *ng* in *fang*. The French word *fin* contains but two elements, a consonant followed by a genuine vowel, whilst the English *fang* has three elements, and ends with a consonant. The mistaking one for the other would be exactly paralleled in the practice of a foreigner who for *pea* would give *peag* as an English word.

This error in regard to the nasals appears in Riggs's valuable Grammar and Dictionary of the Dacota Language, based upon the studies of a number of observers during a period of eighteen years, and submitted to the inspection of a learned committee previous to its publication by the Smithsonian Institution. To a given character the power of 'n' in the French

* Most English grammarians do not distinguish between the length and the quality of their own vowels, regarding *a* and *o* in fāte and ŏbēy as long, and those of făt and ŏbjĕct as short, although, in these examples, the quantity does not differ.

*bon* and English *drink* is assigned, so that the reader is unable to pronounce with certainty the numerous words represented by this character, — an 'n' the second line of which is produced and ends like 'j.' But it is probable that neither the French nor the English sound occurs uniformly, for in the allied Conzo (each *o* as in *not*, *z* in *zeal*) the reporter has heard both, as (to use German characters) in hüng-ga *leggins*, with *ü* long and accented, and *a* short as in *art*. The French sound occurs in the Conzo word for *five*, which is the English syllable *saw* accented and followed by *t* and the French *un*, as if sàwtü$^{n}$. Using '*n*' for Mr. Riggs's letter, the Dacota word for *leggins* is hu*n*ská, and for *five*, zapta*n*.

Independently of the errors of observation, some writers have a practice of referring the sounds they meet with to those of other languages which they may know from description alone; and some proposers of general alphabets supply such foreign sounds with characters, although they run the risk of giving different characters to the same sound, or of confounding distinct sounds. An English alphabet-maker, upon reading that the Lenape (lɛnāpɛ) aborigines use a whistle in speech, might propose a character for it, although this sound is nothing but English *wh* before a consonant, as in whtē *heart* (*e* in *they*), its occurrence in a new connection conveying an impression analogous to that which a new sound would give. In comparisons of sounds, the reader should be informed whether the author has heard those he uses for comparison, and whether his opportunities have been few or many. Some sounds can be accurately described to those unfamiliar with them, as the German *w*, Greek *phi*, English *th* in *thin*, *then*, Welsh aspirate *ll*, *rh*, which latter, together with the Oriental *ghain* and its surd cognate (as they occur in Armenian) the reporter was accustomed to pronounce before he heard them from natives.

The alphabets used by various authors will give a good idea of the state of our knowledge in this department, except that they will not always enable us to establish a parallel between

them. After Rapp's Physiologie der Sprache, the Essentials of Phonetics of Mr. A. J. Ellis, A. B., London, 1848, may be placed, as a conscientious and valuable contribution to the general subject. Being printed in the author's alphabet, its use is restricted to those who can speak English. The alphabetic portion of this treatise is so corrupt, that it ought not to be used for any language; but it has an important concession to correct scholarship, in the use of Cay (and not Kah) as the cognate of Gay.

Castrén's Grammatik der Samojedischen Sprachen (St. Petersburg, 1854) contains a careful analysis of the sounds used. The iotacized (mouillées) consonants, or those followed, and in some cases modified, by the guttural coalescent approaching English y in *million*, are seven in number, *l*, *r*, *n*, *t*, *d*, *s*, and English *z*, marked with a curved line through the stem (on the right of *n*, *d*) of the characters, — an awkward notation requiring too many distinct characters. Ellis uses (j) deprived of its upper and lower dot (as in lȷ,) which is unexceptionable. The peculiarity of these compounds is, that whilst they commence with *l*, &c., the tongue passes to the iotacism before the *l* is completed, *million* being mil$^{l}_{y}$yon when thus iotacized, which, however, is not essential to its purity as an English word. A soft lisped *d* is assigned to Lappish, which is allied to a lisped *r*. The latter quality seems to remove it from English sonant *th* in *then*. This curious sound should be compared with the peculiar Irish *l*, which the reporter first noted as an l-sound mixed with sonant *th*, but subsequently determined to be the sonant analogue of the Welsh surd aspirate *ll*, to which it would bear the same relation that *thy* bears to *thigh*. A sound between *f* and *h* is mentioned, — probably Greek *phi*; and a consonant between *l* and *r*. Castrén assigns a peculiar ụ to Ostiak, and the Russian vowel bl to Samoiede. The latter (which has been heard by the reporter) may be described as a long and short vowel akin to English and German *i* in *still*,* but formed with a more open aperture, and the an-

* This is not the short quantity of the vowel in *field*, and cannot be correctly represented by (ĭ) of the Latin and Italian alphabets.

gles of the lips drawn back. It has the pinched quality of German ö and ü, but without the pursed lips used in forming these well-known vowels.

Böhtlingk (Ueber die Sprache der Jakuten, St. Petersburg, 1851) mentions a nasal of the German J. The reporter* mentions such a sound as present in Wyandot, and a close of the glottis (marked ⊳) which has since been observed in Chippeway. Judging from information received from a European who had resided in Syria, this "close of the glottis" is the Arabic effect termed "spiritus lenis" and marked (') by Lepsius.

S<sup>v</sup>uñić (in German letters Schunjitsch, an Illyrian), De Vera Orthographia, cum Necessariis Elementis Alphabeti Universalis, (Viennæ, 1853,) admits twelve vowels, which, with marks of accent and length, require seventy-two modifications of vowel characters. He supposes that these twelve correspond with the twelve semitones of the musical scale, a view which is fundamentally erroneous. Of the consonants he enumerates fifty, including the mouillé kind, and a few like *ts*, *tsh*, &c. He assigns to the German *w* the power of the English *w*, and considers German *b* in *haben* different from the ordinary *b*, his informant having probably been a provincial. He omits English and German *ng*, or confounds it with the French nasal vowels; and his notation is over-crowded with diacritcal marks.

Poklukar (probably an Illyrian) published a pamphlet at Laibach in 1851, entitled, Ankündigung eines nächst zu veröffentlichenden allgemeinen lateinisch-slavischen, zugleich deutschen, französischen, italienischen und eventuel auch eines Universal- oder Welt- Alphabetes, &c. He confounds German *ng* in *lang* (Eng. *long*) with French *n* in *loin;* and French *v* with German *w*. His notation is objectionable, although he starts with the best possible rule to secure correctness and final

* On some Points of Linguistic Ethnology; with Illustrations, chiefly from the Aboriginal Languages of North America. Proceedings of the American Academy. Cambridge and Boston. October 2, 1849. 8vo.

uniformity, by preventing each author from being influenced by the power which a letter may happen to have in the alphabet he is best acquainted with. This rule requires that *an alphabet should not contradict the Latin original*, Latin being in some sense the (Weltsprache) universal language. The reporter's Elements of Latin Pronunciation (Philadelphia, 1851) grew out of a perception that, without such an investigation, not a single step could be made in the right direction towards a general alphabet, the construction of which should be based rather upon scientific principles than upon the vagaries of each individual who may be called upon to write a language for the first time. Poklukar uses B, F, J, and other letters, correctly, but by a false assumption he uses C as *ts* (although he had already a *t* and an *s* in his alphabet!) and prefers *x* to the Latin Cay or Greek Kappa.

Among the latest works upon the subject* is Professor Lepsius's Allgemeine linguistische Alphabet, (Berlin, 1855,) of which there is an English version, entitled, "Standard Alphabet for reducing Unwritten Languages and foreign graphic Systems to a uniform Orthography in European Letters, &c." (London, 1855.) The profound learning of the author, and the use he has made of his alphabet in the languages of Nubia and Dar Fûr, render this a very important work. It has been approved by the Royal Academy of Berlin, which has had the necessary types cut to give the system publicity; and many of the missionary societies have adopted it, including the English "Church Missionary Society," who have commenced using it in the works of the Rev. S. W. Kölle on the languages of West Africa. Professor Lepsius expresses a hope, that, in cases where missionaries are disposed to make alterations in his notation, "the Committees of Societies will require the reasons of such deviations to be laid before them and discussed."

* Lauth's Vollständige Universal-Alphabet, (München, 1855,) and Professor Max Müller's Languages of the Seat of War in the East ..... with an Appendix on the Missionary Alphabet, — have not yet been received.

This system professes to have a physiological basis, and the labors of the eminent physiologist, Joh. Müller, are acknowledged in this field. Mr. Ellis states that, in Müller's account of the elements, "the faults of a German ear are still conspicuous." Müller (Elements of Physiology, English edition, 1848, p. 1051) does not understand the nature of his own J, which he supposes a sonant German *ch*, as English *z* is a sonant *s*. With him, *m* is not a labial consonant, and he does not know the distinction between *p* and *b*. He considers *p* as having an aspirate quality, probably because an aspirate is made after it, as in pronouncing *tap'*, where a Chinese would say tap'. If *p* in *tap'* and *haphazard* is to be named an *aspirate* from the phase which follows it, the *p* in *pay*, *play* must be a vowel, or the consonant *l*. If the *t* in *boathook* is an aspirate because *h* follows it, it is equally an aspirate when it precedes, as in the Iroquois word ă'ht‌ă.

Professor Lepsius says that in *adna* or *anda* we pronounce "only half the *n* and half the *d*, whilst in *ana* and *ada* we pronounce the whole of *n* and *d*." According to this reasoning, as *n* cuts off the first half of *d* in *anda*, and the last half in *adna*, both halves of the consonant between consonants must be lost in *lend not*, *wends*, *endless*, *string*, *warps*, and in the German proper names *Heindl*, *Jöndl*, *Zarbl*, *Birkl*, *Schmölzl*, *Dietzsch*, &c.

This mode of regarding a consonant position and a vowel position of the organs as in a manner constituting a unitary element, has given rise to alphabets of a more or less syllabic character, like the Cherokee, Ethiopic, Hebrew, and Sanscrit; and the system of Professor Lepsius is heterogeneous in admitting *t* and *a* for *ta*, whilst in the Hottentot dental* clack he uses but one character for the *consonant* position of the organs (a kind of *t*), and the reverberation which follows it in the cavity of the mouth, set in a *vowel* position.

* Mentioned here because it is the only one heard from a native by the reporter, who has, however, heard several others in American languages. A change of notation is required to distinguish the clacks formed by sucking in air from those in which it is expelled.

Professor Lepsius considers the vowel in *worth* as "inherent in all soft fricative consonants," such as English *v*, in which there is indeed sonancy, but no vowel power, and least of all one requiring such open organs as that in *worth.* If anything, the supposed inherent vowel in English *v* is German ü.

A consonant like *l*, *r*, and English *z*, may have the organs so little closed as to approach the vowel quality, and in this case the small circle placed beneath the character by Dr. Lepsius is a good mark. But he uses the mark with *n* and *m* when they form syllables, although in these cases they do not differ from ordinary *m*, *n*. Thus if *z*, in the Chinese word *tsz* quoted by him, is English *z* following *s*, it does not want the mark. In English, the second vowel of *misses*, *horses*, is often omitted in hurried or careless speech, forming the dissyllables *mi-sz*, *hor-sz*, as in *su-dn* (sudden), *pri-sm* (in which *sm* have the same power as in pri-smat-ic), German *v'r-la-ss'n*, *v'r-der-b'n.* In rare cases a mark of syllabication will be necessary, as in *prairie*, often pronounced in English as a trisyllable, with or *without* the vowel of *utter* in the first syllable, in the latter case forming *pr-ai-rie.*

Professor Lepsius follows the English in admitting an "indistinct vowel sound" in nati*o*n, velv*e*t, &c. This is the vowel of wŏrth and ŭrn, which stands on the throat side of the vowel scale, opposite to *awe* on the labial side. It does not yield in distinctness to any of the vowels, but as Latin U and V (English *w*) and I and J are allied, so the vowel in *urn* approximates English smooth *r*, and coalesces with it. Hence, if a person pronounces *ramrod* (ra-mrod), omitting -od, the listener accepts the remainder ra-mr as *rammer.* This so-called "indistinct vowel" is doubtful as a German sound, being more probably elided in *lieb'n*, &c., as it sometimes is in the English words *nation*, *theatr'*, &c. Its resonance may, we are told, be lost "by partially contracting the mouth, or even closing it entirely. In the latter case it is heard through the nose." This supposed vowel is the consonant *m.* The English vowel *awe* is given as an Italian sound, although this lies between *awe*

and *owe* (Ellis, p. 20). But six labial consonants are admitted, *p*, *b*, *m*, *f*, and English *v* and *w*, no mention being made of $\phi$, Ellenic $\beta$, nor English *wh*, although English examples are freely cited, and the number of English consonants stated to be twenty-two. English *wh** was probably supposed to be English *w* (Latin v in QVINQVE, SVAVIS, &c.) preceded by *h*, an opinion in which Professor Lepsius was likely to be seconded by the English committee which he met, and this view would probably be sustained by the missionary committees to whose decision he would have the results of original investigators referred, in case they should differ from the views laid down in the Standard Alphabet.

If such grave errors can take place with the labials, the organs of which can be *seen* and *felt*, in addition to the sounds being *heard*, we may well doubt the analysis of sounds formed out of sight, in the depths of the fauces; and consequently, the following observations are open to correction. Recalling the admission that the reporter has never heard Arabic from a native, yet he is vernacularly familiar with the German smooth aspirate or spirant of *gay* in *re'gen*, which is the sonant of *ch* in *ich*, is free from vibration, and belongs to the *cay* contact. The Ellenic 'gamma (judged by ear from native sources) belongs to the same contact, is made with a similar close of the organs, but has the addition of a mild vibration, probably due to the vibrant action of the *edge*, and not the body, of the palatal veil. The French *r* grasseyée is probably formed by the *body* of the palatal veil, with perhaps little or no contact of the tongue and palate, wherein it would differ from 'gamma.

Some of the Oriental languages have a contact behind that of *cay*, of which *qof* may be considered the characteristic. Aspirating *qof* produces a faucal *qh* analogous to $\chi$, and when this is made sonant the analogy is with aspirate *gay*. Professor Lepsius considers the German aspirate *g*, Ellenic $\gamma$, and

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* In a former paper, the present reporter has affirmed that no orthoepist known to him had been able to state correctly the elements which occur in the English word *when*.

Armenian *ghad* identical, and of course represents them with the same character; and the surd form of *ghad* is considered identical with *ch* in *ich*,—a greater error, apparently, than to confound *cay* and *qof*, or the Arabic "spiritus lenis" (') of Lepsius, with ;ain, as he marks it.

Richardson, in his Arabic Dictionary, says of *ghain:* "This letter is articulated in the throat with a *vibration* producing a sound like that given to *r* by the Northumbrians, or the noise made in *gargling*. . . . It seems to bear the same relation to *kh* as *b* to *p*," — i. e. the relation of sonant to surd. The *kh*, he states, "is generated by a gentle *vibration* in the throat"; consequently it is not the Greek nor German *chi.* Sir William Jones says that "the Persians and Arabs pronounce their *ghain* with a bur in the throat and a tremulous motion of the tongue, as in making the rough *r*"; — and according to Sᵛuñić its surd analogue is an aspirate "qui a graeco χ *chi* in eo differt quod quasi gargarizando efferatur."

These two vibrant sounds appear in the following Armenian words, premising that, as the character for the Armenian *ghad* resembles an angular "2," this will be used for it, whilst ˁQ will represent the surd sound; ə the vowel in *under*, є that in *met;* ᴀ that in *arm*, but short in these examples; ſ English *sh;* c as *k;* and the objectionable character z as in English:—

DZNDZ2Ă′, *a cymbal;* ˁQєLC, *the mind;* ˁQĂTſ, *a crucifix;* ˁQə́ˁQəNTſєL, *a neigh.*

The division of the consonants into contacts is natural, and was appreciated by Aristotle, the Hebrew Grammarians, the Abbé Sicard, &c. A consonant character indicates a closing of the organs, as *p*, *t*, *f*, whether it precedes another effect, as in *fay*, *play;* or follows, as in *off*, or does both, as in *eft.* Each contact is subject to nearly the same phases, that is, if the closed lips make *p*, the tongue will make *t* and its base *k*. Adding sonancy to these gives *b*, *d*, *gay;* open the nasal passage, and these become *m*, *n*, *ng*. Professor Lepsius divides the phases of the contacts into *explosivæ* or *dividuæ*, as *t*, *d*,

*n; fricativæ* or *continuæ*, as *s*, *z;* and *ancipites*, as *r*, *l*. In the labial contact, *p*, *b*, *m* are placed as explosives; *f*, *v*, *w*, (English) as fricatives, without any ancipites; although English *w* is to *b* as *l* is to *d*, and English *y* to *gay*. Apparently to accommodate the German nomenclature, voiceless consonants, as *p*, *f*, are termed *fortis* instead of *surd*, whilst *b* and English *v* are termed *lenis* instead of *sonant*. The fricatives are the aspirates of other authors, whether sonant or surd, except with those who think "sonant aspirate" contradictory, and prefer "spirant" for such elements as English *v*, *z*, and *th* in *then*.

English *w* and *y* (Latin V, J) are *not* fricative in the sense of *f*, *s*, *χ*, &c., but they become so when aspirated in the words *when* and *hue* or *hew*, the initial of which is in neither case *h*, as many suppose. Writing *hue* in Latin letters and marking surd by (ʻ) it will stand ʻJJU or JhJU, English *u* being normally Latin JU.

Instead of twenty-two "simple consonantal sounds" assigned to English by Professor Lepsius, the following may be enumerated:—

| Labial. | Dental. | Palatal. | | Guttural. | Glottal. |
|---|---|---|---|---|---|
| w | l | r | sold*i*er | y | ... |
| wh | ... | ... | nat*u*re | h*u*e | h |
| m | n | ... | ... | ng | ... |
| b | d | ... | ... | g | ... |
| ... v | dh ... | z | zh | ... | ... |
| p | t | ... | ... | k | ... |
| ... f | th ... | s | sh | ... | ... |

To these twenty-six might be added an *r* (as some English people use both a rough and a smooth one), and *mh* for the English and German exclamation *hm* (really ʻmm), a surd aspirate followed by pure *m*. This aspirate is sometimes replaced by ʻ*n* (found in Cherokee) and ʻ*ng*. See Rapp, Vol. II., middle of p. 267, and Vol. I. p. 166, note.

It is here intended to assign to the English word *nature* a

surd, and to *soldier* a sonant effect, allied to *y* in *ye*, *you*, but made at the post-palatal point, and constituting the liquids of which *zh* and *sh* are the aspirate mutes, and into which they are apt to fall, just as *r* may fall into *s* or *z*, or *w* into *v* or *f*. Hence *nature* is often natsh'r, as *soldier* is soldzh'r. In the mouillé effect, the modified *y* is not only drawn forward to the palatal position, but when it follows a dental, this often recedes to meet it, even when the double effect has become t-sh, that is to say, in order to bring *t* nearer to *y*, or to *sh*, it is often drawn back from the teeth, and the point placed against the base of the lower teeth as a fulcrum.*

The notation of the "Standard Alphabet" is defective, whilst tendencies towards uniformity are not fostered by its third and fourth rules, which do not regard the purpose for which a given character was invented. The four rules are: —

I. Every simple sound ought to be represented by a simple sign.

II. Different sounds are not to be expressed by one and the same sign.

III. Those European characters which have a different value in the principal European alphabets, are not to be admitted into a general alphabet.

IV. Explosive letters are not to be used to express fricative sounds, and *vice versa*.

The first two rules are proper, the others are exceptionable. The first is broken by its proposer in assigning a simple character for the contact and the subsequent resonance of the Hottentot clacks. The second is broken by representing the English combination *t-sh* partly by *t* and the character for *sh* (p. 55), and partly (as in Arabic and Persian) by *k* surmount-

* When the iotacism follows a labial or guttural, it can scarcely be called a mouillé effect, although it is so considered in the Slavonic languages. The *t* and *d* thus drawn back to a slight extent in the English t-sh and d-zh, would require little to place them among the palatals, when the *t* would be the lenis of *s*, and the *d* of *z*, or, if nasalized, it would form a sound between *n* and *ng*, perhaps the Sanscrit palatal ña.

ed by an accentual. In Mpongwe (p. 57) this *k'* stands for English *ty*, and on p. 42 *t'* is assigned to *ty* in case it should be required. Hence, in his alphabets of Kúa and Hereró (p. 57) we do not know whether *k'* means *tsh*, *ty*, or even *ky*.

By Rule III. *c*, *ch*, *j*, *x*, are excluded, and most of the characters might have been got rid of by the same unphilosophical process. If in the course of time the measures of the French metre should become shortened, partly by the abrasion incident to use, and partly by the file of avaricious dealers, whilst other dealers, with a higher appreciation of strict accuracy, would preserve their measures at the standard value,—if, under such circumstances, the government were to enforce uniformity, those who had allowed their standard to deteriorate would be clamorous for the retention of their own, as the best known. Strict justice would require that the original metre should be restored, although none but a few just traders might have it in use.

Notwithstanding the nations of Europe have faithfully preserved the vowel characters, even to the y (German ü) of the Danes and Swedes,* there are several alphabets of English origin, which (simulating the weights and measures of certain dealers) fall so far short of the standard that every vowel character, even to that of O, has false powers assigned to it, the opinions and practice of those being disregarded who had for ages kept their standard pure.† No sophistry should induce a Danish missionary to pervert a letter (Y) belonging to, and made for, a *labial vowel*, to the power of a *guttural consonant*. Philologically, it is worse than assigning to Latin, German, Polish, &c. J, the power of English *w*. Let Latin 'V' have its vowel power in *ooze*, 'I' that in *believe*, and 'Y' that of the French *pinched u* (which bears equal relations to this V

* Besides the correct use of Y, the orthography of the Danish word "havn," a haven, (rhyming with *town*,) is strictly Latin.

† Some English authors have gone so far as to assign to Anglish *cay* the power of tsh, as if to flatter superficial readers with a greater resemblance to English. Were this view true, the English words broken, kernel, ache, and kin, would be older than the Anglish brocen, cirnel, ece, and cynn, Irish cine.

and I), when we may account for the form of 'Y' by the following diagram of the affinities of the vowels:—

$$\mathrm{A}\quad \overset{\mathrm{O}}{\mathrm{E}}\quad \overset{\mathrm{V}}{\mathrm{I}}\quad \mathrm{Y}.$$

The rule which rejects C should not retain its cognate G, and that which assigns to the latter its original, standard power in *get*, *give*, should have retained C (or at least a character like *k* deprived of its stem) with its Latin, Gaelic, Welsh, and Anglish power, as Mr. Ellis has done. 'C' (aided by 'Q') is the *normal character* for *cay* in the Romanic languages; and the Latin, German, &c. *ch* is a concession that, if '*ch*' represents the aspirate $\chi$, 'C' without the aspirate mark *h* must normally represent its lenis form *cay*. 'C' is rejected by Rule III., on account of its many perversions, although still used *correctly* in several languages, whilst 'Z,' with as many perversions, is improperly retained with a *corrupt* power. Its powers are as follows:—1. Ancient Greek, as English *zd;* 2. Italian *dz* (and *ts*); 3. German *ts;* 4. English in *azure;* 5. As *s* in Hungarian and Danish, and the German '*tz*'; 6. Its French power; 7. Its Spanish power.

The normal character for the sonant *s* in *rose*, *misery*, is *s*, in German, French, Italian, and English; and as the Latin mode of distinguishing sonant from surd is seen in G, C, the sonant '*s*' should have ended in some similar manner, as by a comma point. In writing, this would degenerate into something like the numeral sign '3,' a form which is used in Russian for English *z*, constituting a very suitable letter. Nevertheless, the adaptability of a Z rounded into a reversed S should be considered.

As English *sh* belongs to a different contact from *s*, it should not be represented by a pointed '*s*,' nor French *j* by a pointed '*z*,' such a mode being as unphilosophical as to represent $\chi$ by a pointed *sh*, or *th* by a pointed *f*. The character ɾ (but not ʃ̣ with its dot and curve below to be written with the stem of script *l* and the tail of *y*, like the German script *h*) was

proposed by Volney for *sh*, and has been used to some extent. For French *j*, the Wallachian form is probably the best, being somewhat like (ȷ) inverted 'f,' with a curved line through the stem, sloped in the direction of the acute accentual. Some such characters are necessary, the paucity of aspirate consonant characters in the Roman alphabet being admitted.

Rule IV. is probably based upon forms like 'th' for the Greek theta, — a false notation for this sound, because theta is not an aspirate of *t*, but a member of a different contact, so that to render theta lenis ('$\theta$) it would be a kind of *t* formed between the teeth; and truly to aspirate *t* (ʻt) would be to form a sound strictly at the *t* contact, with a quality between the aspirates $\theta$ and *s*. Similarly, 's would be *s* deprived of aspiration, forming a kind of *t* posterior to the normal *t*.

The use made by Dr. Lepsius of ($\theta$) for the surd consonant of *thigh* is unexceptionable, but as he wants a character for the sonant of *thy*,* he wavers between $\theta$' and $\delta$, proposing at the same time $\theta$ʻ for $\theta$; thus establishing a complete confusion in the use of the Greek spiritus asper and lenis marks. In $\theta$ʻ an aspirate mark is added to that which is already aspirate, that *surd* may be understood; and in $\theta$' the lenis mark indicates that *vocality* has been added, not to $\theta$ʻ, but to an imaginary $\theta$. In hʻ the aspiration of the Arabic *hha* is enforced, although the Ethiopic character (ሐ) was present in an inverted Greek Ψ-character, which would recall the European idea of *hh*. The ($\chi$) with postposited (') is given for Arabic *ghain* and Ellenic *gamma*, although ($\chi$') ought to mean *k*. In this notation (fʻ) would mean *f*; (f') English *v*;† and (s') English *z*.

* That of Mr. Ellis formed on a (d) basis is probably the best, — or rather its later form in the English phonetic journals.

† There should be a rule to the effect that, *When a character is perverted from its original power, its form should show the variation.* Hence, if prejudice, or ignorance of Latin speech, should prevent a missionary from using (V) with its Latin consonant power, it should be marked to indicate its corrupt English power. Perhaps (ᴠ) might answer, or a break towards the left, in the left branch, like that of italic *k*. This would remove the confusion between *r* and *v* in writing.

To accommodate Sanscrit writing, Professor Lepsius uses (p̊) for *p* and *h* in *uphold*, although all that was necessary was a statement of the fact that, in the Sanscrit alphabet, the sequents ph, bh, &c. (as well as a consonant and vowel in some cases) are supplied by a single character; a statement of this kind being considered sufficient in regard to *ps* having a single character in the Greek form of *ellipsis*. But whilst the spiritus asper and lenis marks are used in these heterogeneous and unauthorized modes, the former is used as a separate character for Arabic and Hebrew *'alef*. This is at least a doubtful view of the Greek spiritus lenis. As applied to a consonant, we see it in ἄῤῥην, *male* (and ἄρσην, because the surd aspirates *rh* and *s** are allied), and Dr. Lepsius admits an (r̊) with a Greek key-word, and he would probably write the Welsh *rh* thus. As applied to a vowel, Chavée (Lexiologie Indo-européenne, p. 18), with great probability, explains the Greek spiritus lenis as the *slight breath* which precedes an initial vowel; for as the vibration of the vocal ligaments is due to the passing air, a little must necessarily pass before their quiescent state can be changed.

Professor Lepsius uses the acute accentual (′) † over (*k*) for *tsh;* over (χ) to distinguish the German *ch* in *ich* from that in *ach;* after (*l*), &c. to denote the mouillé effect; and in ('*l*') the Welsh surd aspirate *l*, for some unexplained reason. To English *sh* and *zh* are assigned *s* and *z* surmounted by the (˘) mark for short quantity, — a perversion of a well-known mark, required, with the mark of length (as in Dacota *s* and *sh*, Riggs, pp. 184, 188), to distinguish long and short continuous

* But Dr. Latham, English Language, 1841, considers *s* the lenis of *sh*. He omits *h*, *wh*, *ng*, *rh*, from his System of Consonants, p. 112, and he considers the mutes specifically distinct to be no more than sixteen. To these add his "Semivowels, *w*, *y*," and "Liquids, *m*, *n*, *l*, *r*," *n* being given as the liquid of *t*, *d;* and *l*, of *k*, *g*.

† As an accent mark, this should be thick above, and for the secondary accent thicker below. If used for other purposes, it should be of equal thickness. Used with ('') for sonant and surd, the middle part should be cut away to give the appearance of two dots in sloped directions.

consonants in some languages. S is thus prolonged in hissing. "The people of Mallicollo use R in many words, two or three being frequently joined together. ..... They express their admiration by hissing like a goose." (Cook's Second Voyage.)

A dot is used over (*n*) by Lepsius, for English and German *ng*, which is equivalent to representing *n* with a dotted *m*-character. Consistency should have required this dot to be (˘), because both indicate that the marked letter belongs to a posterior contact. Ellis's character is much better, — an *n*-character with the second limb ending like (*j*). As a capital (and capitals are of doubtful utility) that of Riggs is a good one, being (N) with the diagonal shaped like a sloped (J.) As a dot is the slightest of marks, it should be used (below the letters) to indicate those slight evanescent consonants and vowels which occur in some languages.

Rule IV., although it cannot be called unphilosophical, would deprive us of a well-known and exceedingly definite mode of notation with the aid of (' ʻ), and obviate the necessity for many new characters in the course of linguistic discovery. By first assuming that *l* and *r* are "fricatives," Professor Lepsius admits (ʻ) with *l*, *r*, but denies it to *n*, *m*, as "explosives," *without providing a means to indicate the same phenomenon* in the latter case. Sjögren (Ossetische Sprachlehre, St. Petersburg, 1844) has a good notation for the aspirates. He uses the Russian alphabet for a basis, and instead of the ordinary *h*, he curves the end towards the left below the line, in the shape of (ɔ), then uses this appendage as the indicator of aspiration and spiration, by adding it to the stem of the Russian characters for *p*, *t*, *g*, and *k*, curving the last line of *k* backwards. For English *dz* he uses $\Delta_з$, which is unnecessary, as the *z* character should appear fully, if the sound exists. Lepsius (p. 69) seems inclined to approve of this mode of writing $t_s$, &c. Such forms should be left for the concurrent emission of consonants formed simultaneously (Rapp, I. 84). Thus a child learning to speak formed *l* by applying the tongue to the upper lip, and passing the voice over the lower lip, producing a sound having the quality of *l* and ʻ*b*.

# PROCEEDINGS

OF THE

# ALBANY MEETING, 1856.

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## COMMUNICATIONS.

## A. MATHEMATICS AND PHYSICS.

### I. MATHEMATICS.

1. On the Laws of Human Mortality. By C. F. M'Cay, President of the South Carolina College, and Professor of Mathematics and Astronomy.

Various attempts have been made to determine the law of human mortality at different periods of life. In the early part of the eighteenth century, it was suggested that an equal number die at every age in a stationary population. The Northampton table of Dr. Price rather favored this suggestion, but other tables of mortality published by him in later editions of his book destroyed all confidence in this law. An arithmetical progression for early manhood, and a geometrical for old age, were then proposed. These not being satisfactory, Mr. Gompertz, in the Philosophical Transactions of 1825, brought forward a transcendental formula which represented the mortality from twenty to sixty years of age with great accuracy. In 1832, Mr. Edmonds extended this law to the whole period of human life, by using two formulas, one for manhood and the other for old age. As the dividing line between these two periods varied from fifty-five to sixty in different tables, and corresponded to no physiological change in our organization, the two laws of Mr. Edmonds did not receive much

favor; and as they involved six variable constants for every table, they were of little practical utility, either for the construction of tables, detecting anomalies, or harmonizing the irregularities which are found in all the statistics of human mortality.

I have obtained a single law which extends from early manhood to the extreme limit of human life. It was first discovered by an analysis of the Northampton and Carlisle tables; but it has been compared with a large number of others; and so complete is its agreement with all, that at no age does the calculated number of the living differ from the number given in the tables by a single year's mortality. The comparison has been made with all the tables to which I have had access. These comprise Halley's, the Switzerland, Vienna, Berlin, Brandenburg, Norwich, London, Northampton, Warrington, Chester, Stockholm, Shrewsbury, Kersebooms, Desparcieux, the three Swedish, the three Equitable, the Amicable, Montpelier, Duvillard's for France, Desparcieux's for monks and nuns, Farr's English, Farr's Northampton, Finlaison's, the Combined Experience of the London Insurance Companies, Nieson's Friendly Societies of Great Britain, Brussels, Hamburg, Amsterdam, Baltimore, Charleston, and others; and, except in the last six or eight years of life, in which no confidence is placed in any of the tables, the disagreement does not exceed the limits above mentioned. The number of the living, as calculated for the age of seventy-five, for example, is always greater than the actual number for seventy-six, and less than for seventy-four. When it is remembered that these tables have been constructed for different times and different countries, by various methods of interpolation, many of them on incomplete and unsatisfactory data, and some on wrong principles, such an agreement will be considered a decisive proof of the law which is proposed.

The extensive interests dependent on the law and the rate of mortality in the United States, Great Britain, and other countries, invest this matter with a high degree of practical importance, independent of the scientific interest attached to the application of a mathematical law to so uncertain a subject as the duration of human life.

If the Northampton table be examined, it will be found that the deaths are either stationary, or increase from the age of ten to sixty-one, and then diminish to the end of life. This increase and decrease are irregular, and follow no definite law. If the ratios of the dying

and the living at each age be examined, a continual increase will be observed. Excluding a few exceptional cases, this advance is found invariable in all the tables. It becomes more rapid at the older ages, but that its progress is not a geometrical progression will be evident by taking the logarithms of these ratios and observing their differences. If, however, these differences be examined, a geometrical progression will be discovered in them. This result shows that the rate of mortality or the ratio of the dying and the living is represented by the formula $ab^{c^x}$, in which $x$ is the age, and $a$, $b$, and $c$ are constants that differ for the several tables. For if the logarithm of this function be taken, it will be evident that $a$ will disappear when the differences are found, and that a geometrical progression will be developed in which $c$ is the constant multiplier.

Here are the numbers from the Northampton table for seven ages, at intervals of ten years: —

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| At the age of | 25 | 35 | 45 | 55 | 65 | 75 | 85 |
| The living were | 4760 | 4010 | 3248 | 2448 | 1632 | 832 | 186 |
| And the dying | 75 | 75 | 78 | 82 | 80 | 80 | 41 |
| The ratios are | .0158 | .0187 | .0240 | .0336 | .0492 | .0943 | .219 |
| Their logarithms | —2.199 | —2.272 | —2.380 | —2.526 | —2.692 | —2.974 | —1.340 |
| The differences are | | .073 | .108 | .146 | .166 | .282 | .366 |
| The ratios are | | | 1.48 | 1.35 | 1.14 | 1.70 | 1.30 |
| Differences for twenty years | | | .181 | .254 | .312 | .448 | .648 |
| The ratios are | | | | 1.40 | 1.23 | 1.44 | 1.45 |
| Differences for thirty years | | | | .327 | .420 | .594 | .814 |
| The ratios are | | | | | 1.29 | 1.41 | 1.37 |
| Differences for forty years | | | | | .493 | .702 | .960 |
| The ratios are | | | | | | 1.42 | 1.37 |
| Average ratios | | | | 1.39 | 1.38 | 1.36 | 1.39 |

None of these ratios differ much from each other, and the averages are very nearly the same. A slight increase of the deaths at sixty-five, and decrease at seventy-five, would make all agree very closely. As the mortality of any single year of life is not to be depended on, this agreement is sufficient to suggest the law which I have proposed. A more careful and extended comparison will be necessary to establish it.

Before doing this, however, let me refer to the principle which underlies it. Mr. Edmonds deduced his law from the supposition that our vital energy, or our power to resist the attacks of disease, decreases continually with advancing years, in such a manner that the portions

of our remaining mortality which we lose at each instant of time increase in geometrical progression. This hypothesis is exceedingly probable, but Mr. Edmonds erred in making these increments correspond to the deaths in a stationary population. By making them represent the increase in the rate of mortality, that is, in the ratio of the dying and the living, the law which I have proposed may be deduced.

If L represent the living and D the dying at any age $x$, $a$, $b$, and $c$ being constants, then, according to Mr. Edmonds, the momentary decrement of L varies with $L\,a^x$ or $-d\,L = L\,a b^x\,dx$. But if the increment is made to refer to the rate of mortality or the ratio of D to L, then if this be called $r$ we have, $d r = r\,\beta\,c^x\,d x$.

Dividing this by $r$ and integrating, we have

$$\log r = c^x \log b + \log a,$$

or

$$\log \frac{r}{a} = c^x \log b,$$

or

$$\frac{r}{a} = b^{c^x} \text{ or } r = a\,b^{c^x}.$$

The partial laws of Mr. Gompertz and Mr. Edmonds differ from mine fundamentally. In theirs, the number of the living follows a certain law; in mine, the law relates to the ratio of the dying and the living. Theirs was limited to manhood or to old age, mine includes both these periods. Mine involves only three constants, and by obtaining the average of these for all ages, the anomalies and errors of the tables may be checked and corrected.

To compare the proposed function with the tables, and to test it for all periods from manhood to old age, the Northampton table is given below, and along with it one calculated from the formula $r = a b^{c^x}$. In this $c = 1.031$, logarithm of $a = -2.986$, and logarithm of logarithm of $b = -2.995$. The agreement between the two tables is seen at a glance to be very close.

If the number of the living at the several ages be examined, it will be seen that the greatest difference occurs at the age of fifty-eight, and only amounts to thirteen, which is less than one sixth of a year's mortality at that age. That is, the number calculated to be alive at the age of fifty-eight is the number found to be living at the age of fifty-seven years and ten months. At eighty-five and eighty-six the difference is twelve, which is about a third of one year's mortality. All expire in both tables at the age of ninety-six; and even when the

number of the living is reduced to fifteen or twenty out of the ten thousand who are supposed to begin the table, the calculated number never disagrees with the tabular by a single year's mortality.

If the deaths in the two tables be examined, it will be found that for thirty ages the number is exactly the same in both. For nineteen they differ only one, and for only a single age, that of eighty-three, does the difference amount to five.

For the first ten years the whole number of the dying is 750, instead of 747. For the next ten it is 753, instead of 750. For each following decade the calculated numbers are

773 805 827 753 424 and 47,

while Dr. Price's are

778 819 806 763 423 and 46;

the difference never amounting to three per cent, and in five out of the eight ten-year periods being less than one per cent. The sum of all the positive and negative errors in the eight decades is only 58.

The most trying test is the annual ratio of mortality. From twenty-one to sixty these do not differ in the two tables by one fortieth of their amount; and up to the age of eighty they do not differ one twentieth; and at no time, to the very end of life, does the difference reach one fifth. These larger errors at the higher ages arise from Dr. Price's imperfect method of interpolation, since the whole number of the dying in the last two decades of life are almost exactly the same in both tables, being 424 and 47, instead of 423 and 46.

The agreement in all these four particulars is very satisfactory. With few of the other tables is it so close as in the Northampton. But in all, the differences are extremely small. At no period of life are the errors in different tables in one direction all positive or all negative. To bring out this comparison, the Equitable table of Mr. Morgan is subjoined. This is founded on the experience of the Equitable Insurance Company of London, from 1752 to 1829. In the calculated table, $c = 1.027$, logarithm of $a = —3.452$, and logarithm of $\log. b = —1.311$.

Up to the age of eighty-five, the greatest difference between the calculated and the actual tables does not exceed six tenths of one year's mortality. The errors are, however, generally different from those of the Northampton.

Thus the greatest excess in the living at Northampton is at the age

of fifty-eight, while the greatest deficiency in the Equitable is at fifty-seven. The greatest deficiency in the Northampton is at seventy-two, and the greatest excess in the Equitable is at seventy-three.

Between thirty and forty, the deaths in both the Northampton and the Equitable are slightly too large; but in the seven other decades the positive errors of one table correspond to the negative errors in the other.

The smallness of all these errors, and their opposite directions in the several tables, furnish satisfactory proof that the formula we have given represents a true law of nature.

Among the inferences that may be drawn from the law are the following: —

1. The rate of mortality invariably increases from youth to old age.

2. This rate is continually accelerated, even in a higher ratio than in a geometrical progression.

3. In early manhood the rate does not differ much from a slow arithmetical progression.

4. There are no crises or climacterics at which the chances for life are stationary or improving.

5. There are no periods of slow and rapid increase succeeding each other; but one steady, invariable progress.

6. The law, though not the rate of mortality, is the same for city and country, for healthy and unhealthy places, for every age and country and locality; and this law is, that the differences of the logarithms of the rates of mortality are in geometrical progression.

*Comparison of the Formula with the Northampton Table of Mortality.*

| Age. | Living of Dr. Price. | Dying. | Calculated Living. | Ratio of Dying and Living. | Number of Dying. | Errors of the Living. | Errors of the Dying. |
|---|---|---|---|---|---|---|---|
| 20 | 5132 | 72 | 5132 | .0147 | 75 | 0 | 3+ |
| 21 | 5060 | 75 | 5057 | .0149 | 75 | 3— | 0 |
| 22 | 4985 | 75 | 4982 | .0151 | 75 | 3— | 0 |
| 23 | 4910 | 75 | 4907 | .0153 | 75 | 3— | 0 |
| 24 | 4835 | 75 | 4832 | .0156 | 75 | 3— | 0 |
| 25 | 4760 | 75 | 4757 | .0158 | 75 | 3— | 0 |
| 26 | 4685 | 75 | 4682 | .0160 | 75 | 3— | 0 |
| 27 | 4610 | 75 | 4607 | .0163 | 75 | 3— | 0 |
| 28 | 4535 | 75 | 4532 | .0165 | 75 | 3— | 0 |
| 29 | 4460 | 75 | 4457 | .0168 | 75 | 3— | 0 |
| 30 | 4385 | 75 | 4382 | .0171 | 75 | 3— | 0 |
| 31 | 4310 | 75 | 4307 | .0174 | 75 | 3— | 0 |
| 32 | 4235 | 75 | 4232 | .0177 | 75 | 3— | 0 |
| 33 | 4160 | 75 | 4157 | .0181 | 75 | 3— | 0 |
| 34 | 4085 | 75 | 4082 | .0184 | 75 | 3— | 0 |
| 35 | 4010 | 75 | 4007 | .0188 | 75 | 3— | 0 |
| 36 | 3935 | 75 | 3932 | .0192 | 75 | 3— | 0 |
| 37 | 3860 | 75 | 3857 | .0196 | 76 | 4— | 1+ |

| Age. | Living of Dr. Price. | Dying. | Calculated Living. | Ratio of Dying and Living. | Number of Dying. | Errors of the Living | Errors of the Dying. |
|---|---|---|---|---|---|---|---|
| 38 | 3785 | 75 | 3781 | .0201 | 76 | 5— | 1+ |
| 39 | 3710 | 75 | 3705 | .0205 | 76 | 6— | 1+ |
| 40 | 3635 | 76 | 3629 | .0209 | 76 | 6— | 0 |
| 41 | 3559 | 77 | 3553 | .0214 | 76 | 6— | 1— |
| 42 | 3482 | 78 | 3477 | .0220 | 77 | 5— | 1— |
| 43 | 3404 | 78 | 3400 | .0226 | 77 | 4— | 1— |
| 44 | 3326 | 78 | 3323 | .0232 | 77 | 3— | 1— |
| 45 | 3248 | 78 | 3246 | .0238 | 77 | 2— | 1— |
| 46 | 3170 | 78 | 3169 | .0245 | 78 | 1— | 0 |
| 47 | 3092 | 78 | 3091 | .0252 | 78 | 1— | 0 |
| 48 | 3014 | 78 | 3013 | .0260 | 78 | 1— | 0 |
| 49 | 2936 | 79 | 2935 | .0268 | 79 | 1— | 0 |
| 50 | 2857 | 81 | 2856 | .0276 | 79 | 1— | 2— |
| 51 | 2776 | 82 | 2777 | .0285 | 79 | 1+ | 3— |
| 52 | 2694 | 82 | 2698 | .0295 | 80 | 4+ | 2— |
| 53 | 2612 | 82 | 2618 | .0305 | 80 | 6+ | 2— |
| 54 | 2530 | 82 | 2538 | .0316 | 80 | 8+ | 2— |
| 55 | 2448 | 82 | 2458 | .0328 | 81 | 10+ | 1— |
| 56 | 2366 | 82 | 2377 | .0340 | 81 | 11+ | 1— |
| 57 | 2284 | 82 | 2296 | .0353 | 81 | 12+ | 1— |
| 58 | 2202 | 82 | 2215 | .0368 | 82 | 13+ | 0 |
| 59 | 2120 | 82 | 2133 | .0384 | 82 | 13+ | 0 |
| 60 | 2038 | 82 | 2051 | .0401 | 82 | 13+ | 0 |
| 61 | 1956 | 82 | 1969 | .0419 | 83 | 13+ | 1+ |
| 62 | 1874 | 81 | 1886 | .0439 | 83 | 12+ | 2+ |
| 63 | 1793 | 81 | 1803 | .0460 | 83 | 10+ | 2+ |
| 64 | 1712 | 80 | 1720 | .0483 | 83 | 8+ | 3+ |
| 65 | 1632 | 80 | 1637 | .0505 | 83 | 5+ | 3+ |
| 66 | 1552 | 80 | 1554 | .0533 | 83 | 2+ | 3+ |
| 67 | 1472 | 80 | 1471 | .0562 | 83 | 1— | 3+ |
| 68 | 1392 | 80 | 1388 | .0594 | 82 | 4— | 2+ |
| 69 | 1312 | 80 | 1306 | .0629 | 82 | 6— | 2+ |
| 70 | 1232 | 80 | 1224 | .0667 | 81 | 8— | 1+ |
| 71 | 1152 | 80 | 1143 | .0708 | 81 | 9— | 1+ |
| 72 | 1072 | 80 | 1062 | .0753 | 80 | 10— | 0 |
| 73 | 992 | 80 | 982 | .0804 | 79 | 10— | 1— |
| 74 | 912 | 80 | 903 | .0857 | 77 | 9— | 3— |
| 75 | 832 | 80 | 826 | .0916 | 76 | 6— | 4— |
| 76 | 752 | 77 | 750 | .0982 | 74 | 2— | 3— |
| 77 | 675 | 73 | 676 | .105 | 71 | 1+ | 2— |
| 78 | 602 | 68 | 605 | .113 | 68 | 3+ | 0 |
| 79 | 534 | 65 | 537 | .123 | 66 | 3+ | 1+ |
| 80 | 469 | 63 | 471 | .133 | 63 | 2+ | 0 |
| 81 | 406 | 60 | 408 | .144 | 59 | 2+ | 1— |
| 82 | 346 | 57 | 349 | .157 | 55 | 3+ | 2— |
| 83 | 289 | 55 | 294 | .171 | 50 | 5+ | 5— |
| 84 | 234 | 48 | 244 | .187 | 46 | 10+ | 2— |
| 85 | 186 | 41 | 198 | .205 | 41 | 12+ | 0 |
| 86 | 145 | 34 | 157 | .225 | 35 | 12+ | 1+ |
| 87 | 111 | 28 | 122 | .248 | 30 | 11+ | 2+ |
| 88 | 83 | 21 | 92 | .274 | 25 | 9+ | 4+ |
| 89 | 62 | 16 | 67 | .304 | 20 | 5+ | 4+ |
| 90 | 46 | 12 | 47 | .338 | 16 | 1+ | 4+ |
| 91 | 34 | 10 | 31 | .378 | 12 | 3— | 2+ |
| 92 | 24 | 8 | 19 | .423 | 8 | 5— | 0 |
| 93 | 16 | 7 | 11 | .475 | 5 | 5— | 2— |
| 94 | 9 | 5 | 6 | .536 | 3 | 3— | 2— |
| 95 | 4 | 3 | 3 | .607 | 2 | 1— | 1— |
| 96 | 1 | 1 | 1 | .691 | 1 | 0 | 0 |

*Comparison with Morgan's Equitable Table of Mortality.*

| Age. | Living in Table. | Dying. | Calculated Number of the Living. | Ratio by Formula. | Dying as Calculated | Errors in the Living | Errors in the Deaths. |
|---|---|---|---|---|---|---|---|
| 20 | 4641 | 34 | 4641 | .0063 | 29 | 0 | 4— |
| 21 | 4607 | 33 | 4612 | .0064 | 30 | 5+ | 3— |
| 22 | 4574 | 33 | 4582 | .0066 | 30 | 8+ | 3— |
| 23 | 4541 | 33 | 4552 | .0067 | 31 | 11+ | 2— |
| 24 | 4508 | 33 | 4521 | .0069 | 31 | 13+ | 2— |
| 25 | 4475 | 34 | 4490 | .0071 | 32 | 15+ | 2— |
| 26 | 4441 | 34 | 4458 | .0073 | 33 | 17+ | 1— |
| 27 | 4407 | 34 | 4425 | .0074 | 33 | 18+ | 1— |
| 28 | 4373 | 34 | 4392 | .0076 | 33 | 19+ | 1— |
| 29 | 4339 | 34 | 4359 | .0078 | 34 | 20+ | 0 |
| 30 | 4305 | 35 | 4325 | .0081 | 35 | 20+ | 0 |
| 31 | 4270 | 35 | 4290 | .0083 | 36 | 20+ | 1+ |
| 32 | 4235 | 36 | 4254 | .0086 | 37 | 19+ | 1+ |
| 33 | 4199 | 37 | 4217 | .0088 | 37 | 18+ | 0 |
| 34 | 4162 | 38 | 4180 | .0091 | 38 | 18+ | 0 |
| 35 | 4124 | 38 | 4142 | .0094 | 39 | 18+ | 1+ |
| 36 | 4086 | 39 | 4103 | .0097 | 40 | 17+ | 1+ |
| 37 | 4047 | 40 | 4063 | .0100 | 41 | 16+ | 1+ |
| 38 | 4007 | 42 | 4022 | .0103 | 41 | 15+ | 1— |
| 39 | 3965 | 43 | 3981 | .0107 | 43 | 16+ | 0 |
| 40 | 3922 | 43 | 3938 | .0111 | 44 | 16+ | 1+ |
| 41 | 3879 | 44 | 3894 | .0115 | 45 | 15+ | 1+ |
| 42 | 3835 | 44 | 3849 | .0119 | 46 | 14+ | 2+ |
| 43 | 3791 | 44 | 3803 | .0124 | 47 | 12+ | 3+ |
| 44 | 3747 | 45 | 3756 | .0129 | 48 | 9+ | 3+ |
| 45 | 3702 | 47 | 3708 | .0134 | 50 | 6+ | 3+ |
| 46 | 3655 | 47 | 3658 | .0140 | 51 | 3+ | 4+ |
| 47 | 3608 | 48 | 3607 | .0147 | 53 | 1— | 5+ |
| 48 | 3560 | 49 | 3554 | .0153 | 54 | 6— | 5+ |
| 49 | 3511 | 50 | 3500 | .0160 | 56 | 11— | 6+ |
| 50 | 3461 | 52 | 3444 | .0168 | 58 | 17— | 6+ |
| 51 | 3409 | 55 | 3386 | .0177 | 60 | 23— | 5+ |
| 52 | 3354 | 58 | 3326 | .0185 | 62 | 28— | 4+ |
| 53 | 3296 | 62 | 3264 | .0195 | 64 | 32— | 2+ |
| 54 | 3234 | 64 | 3200 | .0206 | 66 | 34— | 2+ |
| 55 | 3170 | 66 | 3134 | .0217 | 68 | 36— | 2+ |
| 56 | 3104 | 70 | 3066 | .0229 | 70 | 38— | 0 |
| 57 | 3034 | 75 | 2996 | .0242 | 72 | 38— | 3— |
| 58 | 2959 | 79 | 2924 | .0256 | 75 | 35— | 4— |
| 59 | 2880 | 84 | 2849 | .0272 | 78 | 31— | 6— |
| 60 | 2796 | 88 | 2771 | .0290 | 80 | 25— | 8— |
| 61 | 2708 | 90 | 2691 | .0308 | 83 | 17— | 7— |
| 62 | 2618 | 91 | 2608 | .0329 | 86 | 10— | 5— |
| 63 | 2527 | 93 | 2522 | .0352 | 89 | 5— | 4— |
| 64 | 2434 | 95 | 2433 | .0376 | 92 | 1— | 3— |
| 65 | 2339 | 100 | 2341 | .0403 | 94 | 2+ | 6— |
| 66 | 2239 | 105 | 2247 | .0433 | 97 | 8+ | 8— |
| 67 | 2134 | 108 | 2150 | .0466 | 100 | 16+ | 8— |
| 68 | 2026 | 111 | 2050 | .0502 | 103 | 24+ | 8— |
| 69 | 1915 | 115 | 1947 | .0543 | 106 | 32+ | 9— |
| 70 | 1800 | 115 | 1841 | .0588 | 108 | 41+ | 7— |
| 71 | 1685 | 115 | 1733 | .0640 | 111 | 48+ | 4— |
| 72 | 1570 | 115 | 1622 | .0697 | 113 | 52+ | 2— |
| 73 | 1455 | 115 | 1509 | .0759 | 115 | 54+ | 0 |
| 74 | 1340 | 115 | 1394 | .0829 | 116 | 54+ | 1+ |
| 75 | 1225 | 114 | 1278 | .0906 | 116 | 53+ | 2+ |
| 76 | 1111 | 109 | 1162 | .0995 | 118 | 51+ | 7+ |

| Age. | Living in Table. | Dying. | Calculated Number of the Living. | Ratio by Formula. | Dying as Calculated. | Errors in the Living. | Errors in the Deaths. |
|---|---|---|---|---|---|---|---|
| 77 | 1002 | 105 | 1046 | .110 | 115 | 44+ | 10+ |
| 78 | 897 | 101 | 931 | .121 | 113 | 34+ | 12+ |
| 79 | 796 | 96 | 818 | .134 | 110 | 22+ | 14+ |
| 80 | 700 | 93 | 708 | .149 | 105 | 8+ | 12+ |
| 81 | 607 | 90 | 603 | .165 | 99 | 4— | 9+ |
| 82 | 517 | 85 | 504 | .184 | 93 | 13— | 8+ |
| 83 | 432 | 83 | 411 | .206 | 86 | 21— | 3+ |
| 84 | 349 | 73 | 325 | .230 | 75 | 24— | 2+ |
| 85 | 276 | 61 | 250 | .258 | 64 | 26— | 3+ |
| 86 | 215 | 50 | 186 | .292 | 54 | 29— | 4+ |
| 87 | 165 | 42 | 132 | .331 | 44 | 33— | 2+ |
| 88 | 123 | 34 | 88 | .378 | 33 | 35— | 1— |
| 89 | 89 | 22 | 55 | .433 | 24 | 34— | 2+ |
| 90 | 67 | 18 | 31 | .498 | 15 | 36— | 3— |
| 91 | 49 | 14 | 16 | .575 | 9 | 33— | 5— |
| 92 | 35 | 11 | 7 | .670 | 5 | 28— | 6— |
| 93 | 24 | 8 | 2 | .787 | 2 | 22— | 6— |
| 94 | 16 | 7 | 1 | .933 | 1 | 16— | 7— |
| 95 | 9 | 5 | | | | 9— | 5— |
| 96 | 4 | 3 | | | | 4— | 3— |
| 97 | 1 | 1 | | | | 1— | 1— |

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## 2. Investigation and Calculation of the Results of a Process of Causation. By John Paterson.

"Felix qui potuit rerum cognoscere causas." — Virgil.

(1.) Causes are known to us only by their effects, and are introduced into mathematical reasoning by means of the measures of such effects in space and time. It is conducive to simplicity of calculation to take the effect produced in a given unit of time for unit of effect. The effect is the measure of its cause; and this cause, in its turn, may be the effect of a still higher cause, and so on for several steps in ascending order.

(2.) The phenomenon of a falling body affords an example of *subordinated causation*. The force of gravitation is a constant activity, generating velocity uniformly when acting upon a free material body; and this velocity moves the body with an accelerating rate of motion while it is itself being generated, and with a constant motion after its genesis has ceased. The force of gravity is here a primitive power, or first cause, having velocity for its immediate; while the velocity, in its turn, is the cause of the motion of the body, of its description of

a certain distance in space. The three terms of this ordinated series, in the descending order, may be denominated forces, or powers, or cause respectively of the *second*, *first*, and *zeroth* order, and denoted by the characters $\phi''$, $\phi'$, and $\phi^0$. To obtain suitable measures of the terms, the notion of time must be introduced by its unit $1_t$, and combined with that of the unit of linear space $1_l$. The moved body may be selected as unit of mass $1_\mu$; and the distance it describes in an arbitrarily chosen first unit of time $1'_t$ may be the unit of distance, or linear unit $1_l$.

During the first unit of time $1'_t$, the velocity generated by gravity increases uniformly from zero to a certain ultimate value; and thenceforward, if isolated from the force of gravity, remains constant at that value; which is the same as saying that the unit of mass $1_\mu$ moved from rest with a uniformly accelerated rate of motion during the first unit of time $1'_t$, through the unit of distance $1_l$, and will thenceforward move uniformly with its last acquired rate of motion if the gravity were destroyed. With this last rate of motion, the mobile $1_\mu$ will evidently describe a greater distance in the unit of time than it described while under acceleration in the time $1'_t$; and because the acceleration of the velocity varied regularly, and the units of space and time are of arbitrary magnitude, it follows that, when comparison is made of the effects produced by the velocity in two equal periods of time, the former with regularly varying acceleration, the latter with the ultimate constant value acquired in the first period, the distance described by the mobile $1_\mu$ in the latter period will always be some definite number $m$ of times the distance it described in the former. This is the same thing as saying that the ratio of the distance generated by the ultimate velocity generated in a given time, to the distance generated by the velocity during its own genesis, is that of $m : 1$.

From this it appears that the velocity generated in a given time has two different but fixedly related measures: first, the distance generated by the velocity during its own genesis, which may be termed its *simultaneous* measure; and, secondly, the distance that will be generated by the ultimate velocity remaining constant during an equal time after that of its genesis, and which may be termed its *successive* measure. When the time and distance generated during it are each unity, the former measure of the velocity is unity, and the latter measure will be $m$; and in this case, also, unity will be the simultaneous measure of

the force or power that generates in the unit of time the velocity whose simultaneous and successive measures are 1 and $m$, while $m$ is the successive measure of the same force.

To calculate the value of $m$, let $1_\lambda$ be the unit of velocity, or that constant velocity which will carry the unit mass $1_\mu$ the unit of distance $1_l$ in the unit of time $1_t$. The mobile $1_\mu$ has described the distance $1_l$ in the time $1'_t$ while the velocity $m\ 1_\lambda$ was generated; and it is thence evident that the $m$th part of the ultimate velocity $m\ 1_\lambda$ would carry $1_\mu$, in the unit of time, by a uniform rate of motion, through the same distance $1_l$ that it has been carried by a rate of motion accelerated from zero to the ultimate value $m$; and as the velocity increased uniformly during the unit of time $1'_t$, at the expiration of the first semi-unit of time $\frac{1}{2}' . 1'_t$ its ultimate value is $\frac{m}{2} . 1_\lambda$; with which value, remaining constant, the mobile will describe the distance $\frac{m}{2} . 1_l$ in a unit of time, and consequently the distance $\frac{m}{4} . 1_l$ in the second semi-unit of time $\frac{1}{2}'' . 1'_t$. The ultimate velocity $\frac{m}{2} . 1_\lambda$ generated in the first semi-unit of time $\frac{1}{2}' . 1'_t$, when referred to the measure of the effect it will produce in a time equal to that occupied in its own genesis, therefore becomes $\frac{m}{4} . 1_\lambda$; and the $m$th part of this ultimate velocity, taken constant, will describe with uniform motion the same distance in the time $\frac{1}{2}' . 1'_t$, that was really described by the accelerated motion produced by the uniformly increasing velocity from 0 to $\frac{m}{4} . 1_\lambda$: that common distance is therefore $\frac{1}{4} . 1_l$. During the second semi-unit of time $\frac{1}{2}'' . 1'_t$, another increment $\frac{m}{4} . 1_\lambda$ is generated by the gravitating force, which yields another increment $\frac{1}{4} . 1_l$ of distance during its genesis; and altogether there is generated the distance $(\frac{1}{4} + \frac{m}{4} + \frac{1}{4})\ 1_l = 1_l$ in the unit of time $1'_t$, and this equation gives $m = 2$. Therefore $2 . 1_\lambda = 2\,\phi'$ is the successive unit measure of the effect of the constant force $\phi''$ of the second order, when the simultaneous measure of the same force is $1 . 1_\lambda = 1\,\phi'$, the last for the reason that $1 . 1_\lambda = 1\,\phi'$ produces the effect $1_l = 1\,\phi^0$ in the time $1'_t$.

(3.) Remark. It is undeniable that, in equal times, the ultimate

velocity will generate $m$ times as much distance as will the uniformly increasing velocity; and as the units of time and of space are both arbitrary at the outset, and independent of each other, the magnitude of one of them may be changed without altering that of the other: then if the relation $m : 1$ of the successive to the simultaneous effects be true for any particular time $t$, it must necessarily be true for any other time $2\,t$, $3\,t$, . . . $n\,t$, because the unit of time may be changed without altering that of space.

(4.) If an activity increase from zero during a time $t$, by any regular law of variation, and thenceforward remain a constant activity with its ultimate value, its effect during an equal time must necessarily be some number $m$ of times its effect while in its increasing state. From this it follows that the effect of the increasing activity will be equal to the $m$th part of its effect in an equal time with its ultimate constant value; and that the $m$th part of the ultimate value, taken constant during the time $t$, will produce in that time the same effect as that due to the increasing value.

(5.) The relation above investigated for a series of three ordinated terms $\phi''$, $\phi'$, $\phi^0$, may be generalized for any number $n$ of terms; but to insure merely a sufficient and convenient number of terms for a demonstration, it suffices to take $n = 5$. The condition of unity of effect in the first unit of time will then give the simultaneous series of powers $1\,\phi^{\text{v}}$, $1\,\phi^{\text{iv}}$, $1\,\phi'''$, $1\,\phi''$, $1\,\phi'$, $1\,\phi^0$; while the corresponding successive series will be $1\,\phi^{\text{v}}$, $m\,\phi^{\text{iv}}$, $m'\,\phi'''$, $m''\,\phi''$, $m'''\,\phi'$, $1\,\phi^0$, where the coefficients $m$, $m'$, $m''$, $m'''$ are to be determined.

(6.) Let $\phi^{\text{v}}$ be a primitive cause, a constant activity, force, or power of the fifth order: it will produce a uniform effect in time, consisting in the generation of a certain amount of power of the fourth order $\phi^{\text{iv}}$ in each unit of time $1_t$; which power $\phi^{\text{iv}}$ will generate power of the third order $\phi'''$, which generates power of the second order $\phi''$, which generates power of the first order $\phi'$, which generates power of the order zero $\phi^0$, with which the process terminates. Regarding first only the effects produced in the first unit of time $1'_t$, the final effect $\phi^0$ will be some phenomenon regularly developed in time and space, and which may have for its unit measure the unit of distance $1_l$ described by the unit of mass $1_\mu$ in the unit of time $1'_t$, under the action of the power of the first order $\phi'$. This convention will give the coefficient to the final effect, and also to its immediate cause, of which

it is the unit measure; and further, as the power of the first order is the immediate effect of the power of the second order, and a like relation continues up to the primitive power of the fifth order, it follows that unity will be the coefficient of every term of the series of generating powers enumerated, so long as effects during the first unit of time $1'_t$ only are considered.

Thus the constant power $1\,\phi^{v}$ of the fifth order generates a unit of power of the fourth order $1\,\phi^{iv}$ in the first unit of time $1'_t$, when that power of the fourth order is measured by the power of the third order $\phi'''$ which it generates in the unit of time $1'_t$ of its own genesis. But this generated power of the fourth order increases from zero to some ultimate value during the time $1'_t$; with which ultimate value, remaining constant, it would generate some number $m$ of times the amount of power of the third order in the succeeding unit of time $1''_t$, that was generated by it during the time of its increase or growth in $1'_t$. From this it follows that the $m$th part of the effect of the power $\phi^{iv}$ with its ultimate value, is equal to its effect in an equal time with its increasing value; and that the $m$th part of its ultimate value, taken constant, will produce the same effect in the same time as that produced by the increasing value.

(7.) Let the effects originated, produced, and terminated in the first unit of time $1'_t$ be termed *simultaneous;* and the effects whose causes are produced in the first unit of time, but which are themselves originated, produced, and terminated in the second unit of time $1''_t$, be termed *successive effects.* The simultaneous unit measure of the immediate effect of $1\,\phi^{v}$ is $1\,\phi^{iv}$; but its successive unit measure is $m\,\phi^{iv}$, since the ultimate value of $\phi^{iv}$ generates $m\,\phi'''$ in the time $1''_t$, while it generated only $1\,\phi'''$ while increasing in $1'_t$ to that ultimate value. As $1\,\phi^{v}$ is a uniform generator, its immediate effect increases uniformly from 0 to the value $m\,\phi^{iv}$ in the time $1'_t$, and therefore has the value $\frac{m}{2}\,\phi^{iv}$ at the expiration of the first semi-unit of time $\frac{1}{2}'\,.\,1'_t$. This power $\frac{m}{2}\,\phi^{iv}$, taken constant, would produce the effect $\frac{m}{2}\,\phi'''$ in a unit of time, and therefore actually does produce half that amount $\frac{m}{4}\,\phi'''$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$; and to find the effect of $\frac{m}{2}\,\phi^{iv}$ during the time $\frac{1}{2}'\,.\,1'_t$ of its own genesis or growth, it is only

necessary to divide the last-named amount by $m$, and thus get $\frac{1}{m}\,\phi'''$ for such effect. Another equal increment of power $\frac{m}{2}\,\phi^{\text{IV}}$ is generated by $1\,\phi^{\text{V}}$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$, which generates in like manner the effect $\frac{1}{4}\,\phi'''$ in that time; and as the whole amount of power of the third order generated in the first unit of time must be unity, there appears the equation $(\frac{1}{4} + \frac{m}{4} + \frac{1}{4})\,\phi''' = 1\,\phi'''$, which gives $m = 2$ as the ratio of the successive to the simultaneous measure of the immediate effect of a cause (or of the cause itself) that increases uniformly in time. It is concluded, that, when a product increases uniformly in time, it is the immediate effect of a constant activity; and if the product be itself an activity, half its ultimate value is competent in effect to that of its uniformly increasing value for equal times. Hence the factor 2 and its reciprocal respectively serve to interchange the simultaneous and successive measures of the immediate causal effect of a primitive cause.

Thus accordingly as all is measured by the effects produced in the first unit of time $1'_t$, or as the immediate effect $\phi^{\text{IV}}$ of $1\,\phi^{\text{V}}$ in that time is measured by the effect itself produces in the second unit of time $1''_t$, there exists the first or second of the following notations of results: —

$$\frac{1}{2}'\,.\,1'_t + \frac{1}{2}''\,.\,1'_t = 1'_t. \qquad \frac{1}{2}'\,.\,1'_t + \frac{1}{2}''\,.\,1'_t = 1'_t.$$
$$\frac{1}{2}\,\phi_1^{\text{IV}} + \frac{1}{2}\,\phi_2^{\text{IV}} = 1\,\phi^{\text{IV}};\ \text{or}\ \frac{2}{2}\,\phi_1^{\text{IV}} + \frac{2}{2}\,\phi_2^{\text{IV}} = 2\,\phi^{\text{IV}}.$$

The constant $\frac{1}{2}\,\phi^{\text{IV}}$, and the uniformly increasing $\frac{2}{2}\,\phi^{\text{IV}} = 1\,\phi^{\text{IV}}$, are equivalent in their effects during the same semi-unit of time; and $1\,\phi_1^{\text{IV}}$ constant produces $\frac{2}{4}\,\phi'''$ in $\frac{1}{2}''\,.\,1'_t$, twice the effect $\frac{1}{4}\,\phi'''$ produced by $\frac{1}{2}\,\phi_2^{\text{IV}}$ constant, or by $1\,\phi_2^{\text{IV}}$ variable in that time.

Having now the simultaneous and successive semi-unit measures of the effect of $1\,\phi^{\text{V}}$ for the first unit of time $1'_t$, as also the simultaneous semi-unit measures of the effect of $1\,\phi^{\text{IV}}$ for the same time, the next step is to seek the corresponding successive semi-unit measures of the latter power $\phi^{\text{IV}}$.

The simultaneous semi-unit measures of the immediate effect of the generated power of the fourth order $1\,\phi^{\text{IV}}$ are,

$$\frac{1}{2}'\,.\,1'_t + \frac{1}{2}''\,.\,1'_t = 1'_t.$$
$$\left.\begin{array}{l}\frac{1}{4}\,\phi_1''' + \frac{2}{4}\,\phi''' \\ \qquad + \frac{1}{4}\,\phi_2'''\end{array}\right\} = 1\,\phi'''.$$

These three increments of generated power of the third order are themselves generating powers, and are the constant equivalents in effect of so many increments of generating power of the same order, increasing from zero, during the same semi-units of time. Like as $\frac{1}{2}\,\phi^{\text{IV}}$ was the constant equivalent in effect to the increment increasing from zero to the ultimate value $\frac{m}{2}\,\phi^{\text{IV}}$ in the semi-unit of time, and $m$ was found to be 2; so is $\frac{1}{4}\,\phi'''$ the constant equivalent in effect to an increment increasing from zero to some ultimate value $\frac{m'}{4}\,\phi'''$ in the semi-unit of time, and $m'$ is now sought. Form the equation

$$\tfrac{1}{2}'\,.\,1'_t + \tfrac{1}{2}''\,.\,1'_t = 1'_t:$$

$$\left.\begin{array}{l} \dfrac{m'}{4}\,\phi_1''' + \dfrac{2\,m'}{4}\,\phi''' \\ \qquad + \dfrac{m'}{4}\,\phi_2''' \end{array}\right\} = m'\,\phi''';$$

and observe that while $\frac{m'}{4}\,\phi_1'''$ will be a constant generator during the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$, the increment $\frac{2\,m'}{4}\,\phi'''$, being generated by $\frac{1}{2}\,\phi_1^{\text{IV}}$ constant during $\frac{1}{2}''\,.\,1'_t$, increases uniformly during that time; and therefore its effect must be divided by 2, when it becomes equal to that of $\frac{m'}{4}\,\phi'''$ for the same time.

Now the generated power of the third order increases from zero to the ultimate value $\frac{m'}{4}\,\phi'''$ during the first semi-unit of time $\frac{1}{2}'\,.\,1'_t$; with which value it would generate the increment of power of the second order $\frac{m'}{4}\,\phi''$ in a unit of time, and therefore actually will generate the amount $\frac{m'}{8}\,\phi''$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$, and consequently $\frac{1}{8}\,\phi''$ the $m'$th part of this amount in the time of its own genesis in the first semi-unit $\frac{1}{2}'\,.\,1'_t$; and an equal amount will be due to the generating increment $\frac{m'}{4}\,\phi_2'''$ generated in the second semi-unit $\frac{1}{2}''\,.\,1'_t$ of time. The increment $\frac{2\,m'}{4}\,\phi'''$, being the immediate effect of the constant generator $\frac{1}{2}\,\phi_1^{\text{IV}}$ during the time $\frac{1}{2}''\,.\,1'_t$, increases uniformly, and therefore its effect in that time will be $\frac{2}{8}\,.\,\frac{m'}{4}\,\phi'' = \frac{m'}{4}\,\phi''$

in a unit of time, and consequently $\frac{m'}{8}\,\phi''$ in the semi-unit of time $\frac{1}{2}''\,.\,1'_{t}$. Altogether there arises the equation

$$\left(\tfrac{1}{8} + \frac{m'}{8} + \tfrac{2}{2}\cdot\frac{m'}{8} + \tfrac{1}{8}\right)\phi'' = 1\,\phi'',$$

which gives $m' = 3$ as the ratio of the successive to the simultaneous measures of the mediate effects of a uniformly increasing cause, or of the *bimediate* effects of a constant cause. Hence, as the measure of the effect is the measure of the cause, the factor 3 and its reciprocal respectively serve to interchange the simultaneous and successive measures of the mediate causal effect of a primitive cause.

With $m' = 3$, the successive equations of the generated power of the third order becomes $\left(\tfrac{3}{4} + \tfrac{2\cdot 3}{4} + \tfrac{3}{4}\right)\phi''' = 3\,\phi'''$; and the simultaneous equation of the generated power of the second order at the same time is

$$\tfrac{1}{2}'\,.\,1'_{t} + \tfrac{1}{2}''\,.\,1'_{t} = 1'_{t}:$$

$$\left.\begin{array}{l} \tfrac{1}{8}\,\phi_1'' + \tfrac{3}{8}\,\phi_1'' \\ \qquad\;\; + \tfrac{3}{8}\,\phi_2'' \\ \qquad\;\; + \tfrac{1}{8}\,\phi_2'' \end{array}\right\} = 1\,\phi''.$$

Each of these increments is the constant equivalent in effect for the same time, of so much variable power of the second order, increasing from zero to some ultimate value denoted by $m''$ times the numerical coefficient of the increment considered. During the first semi-unit of time $\frac{1}{2}'\,.\,1'_{t}$, there will be generated a quantity of power of the second order increasing from zero to the ultimate value $\frac{m''}{8}\,\phi''$; and similarly for each of the other increments in the equation, which will then be written for successive measure,

$$\tfrac{1}{2}'\,.\,1'_{t} + \tfrac{1}{2}''\,.\,1'_{t} = 1'_{t}:$$

$$\left.\begin{array}{l} \frac{m''}{8}\,\phi_1'' + \frac{3\,m''}{8}\,\phi_1'' \\ \qquad\quad + \frac{3\,m''}{8}\,\phi_2'' \\ \qquad\quad + \frac{m''}{8}\,\phi_2'' \end{array}\right\} = m''\,\phi''.$$

Now $\frac{m''}{8}\,\phi_1''$ would produce the effect $\frac{m''}{8}\,\phi'$ in a unit of time, and therefore actually generates half that amount $\frac{m''}{16}\,\phi'$ in the semi-unit

$\frac{1}{2}'' . 1'_t$ of time, and consequently the $m''$th part $\frac{1}{16}\,\phi'$ of this amount in the time $\frac{1}{2}' . 1'_t$; which last is also the amount generated by $\frac{m''}{8}\,\phi_2''$ in $\frac{1}{2}'' . 1'_t$. The increment $\frac{3\,m''}{8}\,\phi''$, being the immediate effect of the constant generator $\frac{3}{2}\,\phi_1'''$ during the time $\frac{1}{2}'' . 1'_t$, must have its effect divided by 2, which thus becomes $\frac{3}{2} . \frac{m''}{8}\,\phi'$ for the unit of time, and therefore $\frac{3}{2} . \frac{m''}{16}\,\phi'$ for the time $\frac{1}{2}'' . 1'_t$; and the increment $\frac{3\,m''}{8}\,\phi_2''$, which is the immediate effect of the uniformly increasing generator $\frac{6}{4}\,\phi'''$, or the mediate effect of the constant generator $\frac{1}{2}\,\phi_1^{\text{IV}}$, during the time $\frac{1}{2}'' . 1'_t$, must have its effect divided by 3, which thus becomes $\frac{3}{3} . \frac{m''}{8}\,\phi'$ for the unit of time, and therefore $\frac{3}{3} . \frac{m''}{16}\,\phi'$ for the time $\frac{1}{2}'' . 1'_t$. Altogether there arises the equation

$$\left(\tfrac{1}{16} + \frac{m''}{16} + \tfrac{3}{2} . \frac{m''}{16} + \tfrac{3}{3} . \frac{m''}{16} + \tfrac{1}{16}\right)\phi' = 1\,\phi',$$

which gives $m'' = 4$ as the ratio of the successive to the simultaneous measure of the trimediate effects of a constant cause. Hence, the factor 4 and its reciprocal mutually serve to interchange the simultaneous and successive measures of the bimediate causal effects of a primitive cause.

With $m'' = 4$, the successive equation of the generated power of the second order becomes $(\frac{4}{8} + \frac{12}{8} + \frac{12}{8} + \frac{4}{8})\,\phi'' = 4\,\phi''$; and the simultaneous equation of the generated power of the first order at the same time is

$$\tfrac{1}{2}' . 1'_t + \tfrac{1}{2}'' . 1'_t = 1'_t:$$

$$\left.\begin{aligned} \tfrac{1}{16}\,\phi_1' &+ \tfrac{4}{16}\,\phi_1' \\ &+ \tfrac{6}{16}\,\phi' \\ &+ \tfrac{4}{16}\,\phi_2' \\ &+ \tfrac{1}{16}\,\phi_2' \end{aligned}\right\} = 1\,\phi'.$$

Each increment is the constant equivalent in effect, for the same time, of so much power of the first order, increasing from zero to some ultimate value denoted by $m'''$ times its numerical coefficient. During the first semi-unit of time $\frac{1}{2}' . 1'_t$, the generated power of the first order increases from zero to the ultimate value $\frac{m'''}{16}\,\phi'$; and simi-

larly for each of the other increments, so that the equation for successive measures is

$$\tfrac{1}{2}' \,.\, 1'_{t} + \tfrac{1}{2}'' \,.\, 1'_{t} = 1'_{t}:$$

$$\left.\begin{aligned} \frac{m'''}{16}\,\phi_1' &+ \frac{4\,m'''}{16}\,\phi_1' \\ &+ \frac{6\,m'''}{16}\,\phi' \\ &+ \frac{4\,m'''}{16}\,\phi_2' \\ &+ \frac{m'''}{16}\,\phi_2' \end{aligned}\right\} = m'''\,\phi'.$$

Now $\frac{m'''}{16}\,\phi_1'$ would produce the effect $\frac{m'''}{16}\,\phi^0$ in a unit of time, and therefore actually does generate half that amount $\frac{m'''}{32}\,\phi^0$ in the second semi-unit of time $\tfrac{1}{2}''\,.\,1'_{t}$, and consequently the $m'''$th part of it $\tfrac{1}{32}\,\phi^0$ in the first semi-unit $\tfrac{1}{2}'\,.\,1'_{t}$ of time; which last is also the amount generated by $\frac{m'''}{16}\,\phi_2'$ in the second semi-unit $\tfrac{1}{2}''\,.\,1'_{t}$ of time.

The increment $\frac{4\,m'''}{16}\,\phi_1'$ is the immediate effect of the constant generator $\tfrac{4}{8}\,\phi_1''$ during the time $\tfrac{1}{2}''\,.\,1'_{t}$, and must therefore have its effect divided by 2, which thus becomes $\tfrac{4}{2}\,.\,\frac{m'''}{16}\,\phi^0$ for the unit of time, and consequently $\tfrac{4}{2}\,.\,\frac{m'''}{32}\,\phi^0$ for the time $\tfrac{1}{2}''\,.\,1'_{t}$.

The increment $\frac{6\,m'''}{16}\,\phi'$ is the mediate effect of the constant generator $\tfrac{3}{4}\,\phi_1'''$ during the time $\tfrac{1}{2}''\,.\,1'_{t}$, and must therefore have its effect divided by 3, which thus becomes $\tfrac{6}{3}\,.\,\frac{m'''}{16}\,\phi^0$ for the unit of time, and consequently $\tfrac{6}{3}\,.\,\frac{m'''}{32}\,\phi^0$ for the time $\tfrac{1}{2}''\,.\,1'_{t}$.

The increment $\frac{4\,m'''}{16}\,\phi_2'$ is the bimediate effect of the constant generator $\tfrac{1}{2}\,\phi_1^{\mathrm{IV}}$ during the time $\tfrac{1}{2}''\,.\,1'_{t}$, and must have its effect divided by 4, which thus becomes $\tfrac{4}{4}\,.\,\frac{m'''}{16}\,\phi^0$ for the unit of time, or $\tfrac{4}{4}\,.\,\frac{m'''}{32}\,\phi^0$ for the time $\tfrac{1}{2}''\,.\,1'_{t}$. All together fetch the equation

$$\left(\tfrac{1}{32} + \frac{m'''}{32} + \tfrac{4}{2} \cdot \frac{m'''}{32} + \tfrac{6}{3} \cdot \frac{m'''}{32} + \tfrac{4}{4} \cdot \frac{m'''}{32} + \tfrac{1}{32}\right) \phi^0 = 1\, \phi^0,$$

which gives $m''' = 5$ as the ratio of the successive to the simultaneous measure of the quatrimediate effects of a constant cause. Hence, the factor 5 and its reciprocal mutually serve to interchange the simultaneous and successive measures of the trimediate causal effects of a primitive cause.

With $m''' = 5$, the successive equation of the generated power of the first order becomes $(\frac{5}{16} + \frac{20}{16} + \frac{30}{16} + \frac{20}{16} + \frac{5}{16})\, \phi' = 5\, \phi'$; and the simultaneous equation of the generated power of the order zero at the same time is $(\frac{1}{32} + \frac{5}{32} + \frac{10}{32} + \frac{10}{32} + \frac{5}{32} + \frac{1}{32})\, \phi^0 = 1\, \phi^0$.

(8.) In an investigation so opposed to the ordinary methods of mathematical reasoning, some repetitions may be allowed.

Two principles govern and suffice to explain the process of mathematical development: —

I. The measure of an effect stands as the measure of its cause.

II. The successive and simultaneous measures of a regularly increasing cause or power have to each other a determinate ratio.

Under the first principle, it is allowable to select for unit of effect that which is produced in the unit of time, which will then be the unit measure of its immediate cause: this cause, in its turn, may be the immediate effect of a cause one degree higher, of which it will, consequently, be also the unit measure; and so on, for any number of steps of ascent fixed upon. If, then, the primitive cause or power selected be of the fifth order, there will be established the series of simultaneous causes or powers $1\,\phi^{\mathrm{v}}$, $1\,\phi^{\mathrm{iv}}$, $1\,\phi'''$, $1\,\phi''$, $1\,\phi'$, $1\,\phi^0$; the measure of each, throughout the series, being unity *in and for* the first unit of time $1'_t$ of the operative process.

The second principle merely embodies the self-evident proposition, that if an activity increase from zero according to some regular law during a given time, and then remain constant with its ultimate value for an equal time, its effect in the latter interval will be some definite number of times its effect in the former interval of time. This proposition embraces two precepts of direct application to the construction and interpretation of the process of development.

1. If the ultimate value of an activity enable it to produce $m$ times its preceding effect, the times being equal, then the $m$th part of the successive effect is equal to the simultaneous effect of the activity.

2. The $m$th part of the ultimate value is the constant value of the activity that will produce the same effect it did produce while increasing from zero to that ultimate value, the times being equal.

(9.) The power of the fifth order $1\,\phi^{\text{v}}$ is a constant uniform activity, and hence generates power of the fourth order uniformly in time. As its simultaneous measure, according to the first principle, is to be unity, its effect in and for the time $1'_t$ is $1\,\phi^{\text{IV}}$; and as its action is uniform, it generates $\frac{1}{2}\,\phi_1^{\text{IV}}$ and $\frac{1}{2}\,\phi_2^{\text{IV}}$ in the semi-units of time $\frac{1}{2}'\,.\,1'_t$ and $\frac{1}{2}''\,.\,1'_t$ respectively. These measures are constant values, and are the same as though $\phi^{\text{IV}}$ were an inactivity. But the generated power of the fourth order is itself an activity, and generates power of the third order both during and after its own genesis in the first unit of time $1'_t$; and as it increases regularly from zero during the time of its genesis, it is evident that with its ultimate constant magnitude during an equal time it will produce some definite number $m$ of times its preceding effect. Consequently, the amount of power of the fourth order generated by $1\,\phi^{\text{v}}$ in the time $1'_t$, for the time $1''_t$, will be expressed by $m\,\phi^{\text{IV}}$, or $m$ will be the ratio of the successive to the simultaneous measure of the generated power of the fourth order; and therefore, by uniformity of genesis, the amounts for the times $\frac{1}{2}'\,.\,1'_t$ and $\frac{1}{2}''\,.\,1'_t$ respectively are $\frac{1}{2}\,m\,\phi_1^{\text{IV}}$ and $\frac{1}{2}\,m\,\phi_2^{\text{IV}}$. The ultimate value or simultaneous measure $\frac{1}{2}\,m\,\phi_1^{\text{IV}}$ would generate $\frac{1}{2}\,m\,\phi'''$ in a unit of time, and therefore actually does generate $\frac{1}{4}\,m\,\phi'''$ in the semi-unit of time $\frac{1}{2}''\,.\,1'_t$; and consequently, by the first precept, it has generated $\frac{1}{4}\,\phi'''$ in the time $\frac{1}{2}'\,.\,1'_t$ of its own genesis. The increment $\frac{1}{2}\,m\,\phi_2^{\text{IV}}$ generated by $1\,\phi^{\text{v}}$ in the second semi-unit of time $\frac{1}{2}''\,.\,1'_t$, would also generate $\frac{1}{2}\,m\,\phi'''$ in a unit of time, or $\frac{1}{4}\,m\,\phi'''$ in a semi-unit of time after its genesis, and therefore actually has generated $\frac{1}{4}\,\phi_2'''$ in the time $\frac{1}{2}''\,.\,1'_t$ of its own genesis. There is thus obtained the equation $(\frac{1}{4}+\frac{m}{4}+\frac{1}{4})\,\phi'''=1\,\phi'''$, the simultaneous measure of the generated power of the third order for the time $1'_t$; which gives $m=2$: whence $2\,\phi^{\text{IV}}$ is the ultimate value, or the successive measure of the power of the fourth order generated by $1\,\phi^{\text{v}}$ in a unit of time, or $2:1$ is the ratio of the successive and simultaneous measures of a power that increases uniformly.

The increment generated by $1\,\phi^{\text{v}}$ in the times $\frac{1}{2}'\,.\,1'_t$ and $\frac{1}{2}''\,.\,1'_t$ are therefore respectively $\frac{2}{2}\,\phi_1^{\text{IV}}=1\,\phi_1^{\text{IV}}$ and $\frac{2}{2}\,\phi_2^{\text{IV}}=1\,\phi_2^{\text{IV}}$. Each of these increments increases from zero to $1\,\phi^{\text{IV}}$ in the semi-unit of time;

and by the second precept, the half of the ultimate value, or $\frac{1}{2}\,\phi^{\text{IV}}$, taken constant, will produce the same effect as the variable in the same time. Now $\frac{1}{2}\,\phi^{\text{IV}}$ would generate $\frac{1}{2}\,\phi'''$ in a unit of time, or $\frac{1}{4}\,\phi'''$ in a semi-unit of time. Therefore the constants $\frac{1}{2}\,\phi_1^{\text{IV}}$ and $\frac{1}{2}\,\phi_2^{\text{IV}}$ produce the same effects $\frac{1}{4}\,\phi_1'''$ and $\frac{1}{4}\,\phi_2'''$ as the variables $\frac{2}{2}\,\phi_1^{\text{IV}}$ and $\frac{2}{2}\,\phi_2^{\text{IV}}$ in the times $\frac{1}{2}'\,.\,1'_t$ and $\frac{1}{2}''\,.\,1'_t$ respectively, and the constant $\frac{2}{2}\,\phi_2^{\text{IV}}$ produces $\frac{2}{4}\,\phi'''$ in $\frac{1}{2}''\,.\,1'_t$; making in all $(\frac{1}{4}+\frac{2}{4}+\frac{1}{4})\,\phi'''=1\,\phi'''$, which is the same as though $\phi'''$ were an inactivity. But the generated power of the third order is itself an activity, and generates power of the second order increasingly during its own genesis, and uniformly afterwards.

The constant $\frac{1}{2}\,\phi_1^{\text{IV}}$ (equivalent of the variable increasing from zero to $\frac{2}{2}\,\phi_1^{\text{IV}}$) would produce the effect $\frac{m'}{4}\,\phi_1'''$ in the time $\frac{1}{2}'\,.\,1'_t$: this increment $\frac{m'}{4}\,\phi_1'''$ would produce the effect $\frac{m'}{4}\,\phi''$ in a unit of time after its genesis, and therefore does produce the effect $\frac{m'}{8}\,\phi_1''$ in the time $\frac{1}{2}''\,.\,1'_t$, and consequently has produced the effect $\frac{1}{8}\,\phi_1''$ in the time $\frac{1}{2}'\,.\,1'_t$ of its own genesis; and the same amount $\frac{1}{8}\,\phi_2''$ will result from the constant increment $\frac{1}{2}\,\phi_2^{\text{IV}}$ (equivalent of the variable $\frac{2}{2}\,\phi_2^{\text{IV}}$) in the time $\frac{1}{2}''\,.\,1'_t$. But the increment $\frac{m'}{4}\,\phi_1'''$ (which generates $\frac{m'}{8}\,\phi_1''$ in $\frac{1}{2}''\,.\,1'_t$, and has generated $\frac{1}{8}\,\phi_1''$ in $\frac{1}{2}'\,.\,1'_t$) was really generated by the variable $\frac{2}{2}\,\phi_1^{\text{IV}}$ in $\frac{1}{2}'\,.\,1'_t$; and as this increment has increased uniformly during $\frac{1}{2}'\,.\,1'_t$, and remains constant during $\frac{1}{2}''\,.\,1'_t$, it will in this time generate twice its preceding effect, which is therefore $2\,\frac{m'}{4}\,\phi'''$. This increment $2\,\frac{m'}{4}\,\phi'''$, remaining constant after its genesis in $\frac{1}{2}''\,.\,1'_t$, would produce the effect $2\,\frac{m'}{4}\,\phi''$ in a unit of time, or $2\,\frac{m'}{8}\,\phi''$ in a semi-unit of time; but being itself generated by the constant $2\,\frac{m'}{4}\,\phi'''$ in the time $\frac{1}{2}''\,.\,1'_t$, it increased uniformly, and does therefore generate half the preceding effect in that time, that is, the amount $\frac{2}{2}\,.\,\frac{m'}{8}\,\phi''$. Thus is obtained the equation $(\frac{1}{8}+\frac{m'}{8}+\frac{2}{2}\,.\,\frac{m'}{8}+\frac{1}{8})\,\phi''=1\,\phi''$, which gives $m'=3$; whence $3\,\phi'''$ is the ultimate value of the power of the third

order generated by the power of the fourth order increasing from zero to the value $2\,\phi^{\text{iv}}$ in the unit of time $1'_t$. The generated power of the third order $3\,\phi'''$ will produce thrice the effect in the time $1''_t$, that it produced during its genesis in the time $1'_t$: also its ultimate value for the time $\frac{1}{2}'\,.\,1'_t$ is $\frac{3}{4}\,\phi'''$, which generates $\frac{3}{8}\,\phi''$ in the time $\frac{1}{2}''\,.\,1'_t$; and one third of which value, $\frac{1}{4}\,\phi'''$, being constant during the time $\frac{1}{2}'\,.\,1'_t$, would generate $\frac{1}{8}\,\phi''$, the same actually generated by the variable $\frac{3}{4}\,\phi'''$ in that time.

To find the measures of the generated increments of power of the second order in terms of their effect in power of the first order, observe that the constant $\frac{1}{4}\,\phi_1'''$ (equivalent of the variable increasing from zero to $\frac{3}{4}\,\phi_1'''$) would generate the increment $\frac{m''}{8}\,\phi_1''$ in the time $\frac{1}{2}'\,.\,1'_t$; which increment $\frac{m''}{8}\,\phi_1''$ would generate the effect $\frac{m''}{8}\,\phi_1'$ in a unit of time, and therefore does generate $\frac{m''}{16}\,\phi_1'$ in the time $\frac{1}{2}''\,.\,1'_t$, and consequently has generated $\frac{1}{16}\,\phi_1'$ during the time of its own genesis in $\frac{1}{2}'\,.\,1'_t$; and the same amount $\frac{1}{16}\,\phi_2'$ will result from the constant increment $\frac{1}{4}\,\phi_2'''$ (equivalent of the variable $\frac{3}{4}\,\phi_2'''$) in the time $\frac{1}{2}''\,.\,1'_t$. But the increment $\frac{m''}{8}\,\phi_1''$ (which generates $\frac{m''}{16}\,\phi_1'$ in $\frac{1}{2}''\,.\,1'_t$, and has generated $\frac{1}{16}\,\phi_1'$ in $\frac{1}{2}'\,.\,1'_t$) was really generated by the variable $\frac{3}{4}\,\phi_1'''$ in $\frac{1}{2}'\,.\,1'_t$; and as this increment has increased in a triplicate ratio during $\frac{1}{2}'\,.\,1'_t$, and remains constant during $\frac{1}{2}''\,.\,1'_t$, it will in this time generate thrice its preceding effect, which is therefore $3\,\frac{m''}{8}\,\phi''$. This increment $3\,\frac{m''}{8}\,\phi''$, remaining constant after its genesis in $\frac{1}{2}''\,.\,1'_t$, would generate $3\,\frac{m''}{8}\,\phi'$ in a unit of time, or $3\,\frac{m''}{16}\,\phi'$ in a semi-unit of time; but being itself generated by the constant $\frac{3}{4}\,\phi_1'''$ in the time $\frac{1}{2}''\,.\,1'_t$, it increases uniformly, and does therefore generate half the preceding effect in that time, that is, the amount $\frac{3}{2}\,.\,\frac{m''}{16}\,\phi'$. The increment $2\,.\,\frac{3}{4}\,\phi'''$, being constant during $\frac{1}{2}''\,.\,1'_t$, must have its effect during that time divided by 2, when it will be $3\,\frac{m''}{8}\,\phi_2''$, the same as that of the increment $\frac{3}{4}\,\phi_1'''$: the effect of $\frac{3}{8}\,m''\,\phi_2''$ during a semi-unit of time after its genesis would be $\frac{3}{16}\,m''\,\phi'$; but since it has

increased during $\frac{1}{2}'' . 1'_t$ in a triplicate ratio, its effect in that time is $\frac{3}{8} . \frac{m''}{16} \phi_1'$. Thus is obtained the equation

$$(\tfrac{1}{16} + \frac{m''}{16} + \tfrac{3}{2}\frac{m''}{16} + \tfrac{3}{8}\frac{m''}{16} + \tfrac{1}{16})\,\phi' = 1\,\phi',$$

which gives $m'' = 4$; whence $4\,\phi''$ is the ultimate value of the power of the second order generated by the power of the third order while increasing from zero to the value $3\,\phi'''$ in the first unit of time $1'_t$. The generated power of the second order $4\,\phi''$ will produce four times the effect in the time $1''_t$ that it produced in the time of its genesis in $1'_t$.

The constant $\frac{1}{8}\phi_1''$ (equivalent of the variable increasing from zero to the value $\frac{1}{8}\phi_1''$ in the time $\frac{1}{2}' . 1'_t$) would generate the increment $\frac{m'''}{16}\phi_1'$ in that time; which last increment would generate the effect $\frac{m'''}{16}\phi_1^0$ in a unit of time, and therefore does generate $\frac{m'''}{32}\phi_1^0$ in the time $\frac{1}{2}'' . 1'_t$, and consequently has generated $\frac{1}{32}\phi_1^0$ in the time $\frac{1}{2}' . 1'_t$ of its own genesis; and the same amount $\frac{1}{32}\phi_2^0$ will result from the constant increment $\frac{1}{8}\phi_2''$ (equivalent of the variable $\frac{1}{8}\phi_2''$ in the time $\frac{1}{2}'' . 1'_t$). But the increment $\frac{m'''}{16}\phi_1'$ was really generated by the variable $\frac{1}{8}\phi_1''$ in $\frac{1}{2}' . 1'_t$; and as this increment has increased in a quadruplicate ratio, during $\frac{1}{2}' . 1'_t$, and remains constant during $\frac{1}{2}'' . 1'_t$, it will in this time generate $4\,\frac{m'''}{16}\phi_1'$, four times its preceding effect. This increment $4\,\frac{m'''}{16}\phi_1'$, remaining constant after its genesis in $\frac{1}{2}'' . 1'_t$, would generate $4\,\frac{m'''}{16}\phi_1^0$ in a unit of time, or $\frac{4\,m'''}{32}\phi_1^0$ in a semi-unit of time; but being itself generated by the constant $\frac{1}{8}\phi_1''$ in the time $\frac{1}{2}'' . 1'_t$, it increases uniformly, and therefore generates $\frac{1}{2} . \frac{m'''}{32}\phi_1^0$ in that time.

The increment $\frac{3}{4}\phi_1'''$ is constant during $\frac{1}{2}'' . 1'_t$, and generates $3 . \frac{1}{8}\phi_1''$ in that time; this increment, increasing uniformly, generates $\frac{3}{2} . \frac{4\,m'''}{16}\phi_1'$ in the time $\frac{1}{2}'' . 1'_t$; and this last increment, remaining constant after its genesis, would generate $\frac{6\,m'''}{16}\phi^0$ in a unit of time, or

$\frac{6\,m'''}{32}$, $\phi^0$ in a semi-unit of time; but being itself generated in $\frac{1}{2}''.1'_t$ by a uniformly increasing power, its effect increases in a triplicate ratio, and therefore it generates $\frac{6}{3}.\frac{m'''}{32}\,\phi^0$ in that time.

The increment $\frac{2}{2}\,\phi_1^{\text{IV}}$ is constant during $\frac{1}{2}''.1'_t$, and generates $2.\frac{3}{4}\,\phi'''$ in that time: this increment, increasing uniformly, generates $\frac{2}{2}.\frac{3}{8}\frac{4}{}\,\phi''$ in the time $\frac{1}{2}''.1'_t$: this increment, increasing in a duplicate ratio, generates $\frac{6}{3}.\frac{4\,m'''}{16}\,\phi'$ in the time $\frac{1}{2}''.1'_t$; and this last increment, remaining constant after genesis, would generate $\frac{4\,m'''}{16}\,\phi^0$ in a unit of time, or $\frac{4\,m'''}{32}\,\phi^0$ in a semi-unit of time; but being itself generated in $\frac{1}{2}''.1'_t$ by a power that increases in a triplicate ratio, its effect increases in a quadruplicate ratio, and therefore reduces to $\frac{4}{4}.\frac{m'''}{32}\,\phi^0$ for the time $\frac{1}{2}''.1'_t$. There is thus obtained the equation

$$\left(\tfrac{1}{32}+\frac{m'''}{32}+\tfrac{4}{2}.\frac{m'''}{32}+\tfrac{6}{3}.\frac{m'''}{32}+\tfrac{4}{4}.\frac{m'''}{32}+\tfrac{1}{32}\right)\phi^0=1\,\phi^0,$$

which gives $m'''=5$; whence $5\,\phi'$ is the ultimate value of the power of the first order generated by the power of the second order increasing from zero to $4\,\phi''$, generated by the power of the third order increasing from zero to $3\,\phi'''$, generated by the power of the fourth order increasing from zero to $2\,\phi^{\text{IV}}$, generated by the constant primitive power of the fifth order $1\,\phi^{\text{V}}$ in the first unit of time $1'_t$.

(10.) A reference to the accompanying table may assist to render the steps of the investigation more intelligible. Under the first division of effects, the dotted lines refer to the effects that *would be* produced during the times for which they are drawn, while the black lines indicate the effects that *are* produced. The last division exhibits the corresponding measures of the effects in space, in and for the time $\frac{1}{2}'.1'_t+\frac{1}{2}''.1'_t=1'_t$.

(11.) In the following tablet of successive measures, the successively introduced numerical factors are all retained in the subsequent coefficients: —

$$1\,\phi^{\text{v}} :$$

$$\begin{array}{rcll}
\underbrace{\tfrac{1}{2}'\,.\,1'_t}_{} & + & \underbrace{\tfrac{1}{2}''\,.\,1'_t}_{} & = 1'_t. \\
2\,.\,\tfrac{1}{2}\,\phi^{\text{IV}} & + & 2\,.\,\tfrac{1}{2}\,\phi^{\text{IV}} & = 2\,\phi^{\text{IV}}\,; \\
\tfrac{2}{2}\,.\,3\,.\,\frac{1}{2^2}\,\phi''' & + & \left.\begin{array}{r} 2\,.\,3\,.\,\frac{1}{2^2}\,\phi''' \\ \tfrac{2}{2}\,.\,3\,.\,\frac{1}{2^2}\,\phi''' \end{array}\right\} & = 3\,\phi'''\,; \\
\tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,4\,.\,\frac{1}{2^3}\,\phi'' & + & \left.\begin{array}{r} 3\,.\,4\,.\,\frac{1}{2^3}\,\phi'' \\ +\ \tfrac{2}{2}\,.\,3\,.\,4\,.\,\frac{1}{2^3}\,\phi'' \\ +\ \tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,4\,.\,\frac{1}{2^3}\,\phi'' \end{array}\right\} & = 4\,\phi''\,; \\
\tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,\tfrac{4}{4}\,.\,5\,.\,\frac{1}{2^4}\,\phi' & + & \left.\begin{array}{r} 4\,.\,5\,.\,\frac{1}{2^4}\,\phi' \\ +\ \tfrac{2}{2}\,.\,4\,.\,5\,.\,\frac{1}{2^4}\,\phi' \\ +\ \tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,4\,.\,5\,.\,\frac{1}{2^4}\,\phi' \\ +\ \tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,\tfrac{4}{4}\,.\,5\,.\,\frac{1}{2^4}\,\phi' \end{array}\right\} & = 5\,\phi'\,; \\
\tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,\tfrac{4}{4}\,.\,\tfrac{5}{5}\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 & + & \left.\begin{array}{r} 5\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 \\ +\ \tfrac{4}{2}\,.\,5\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 \\ +\ \tfrac{3}{2}\,.\,\tfrac{4}{3}\,.\,5\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 \\ +\ \tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,\tfrac{4}{4}\,.\,5\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 \\ +\ \tfrac{2}{2}\,.\,\tfrac{3}{3}\,.\,\tfrac{4}{4}\,.\,\tfrac{5}{5}\,.\,1\,.\,\frac{1}{2^5}\,\phi^0 \end{array}\right\} & = 1\,\phi^0.
\end{array}$$

By introducing the denominators 2, 3, 4, 5 into the coefficients of the terms of the respective groups in descending order, the successive are converted into simultaneous measures.

Whatever be the order $n$ of a primitive constant generator, its immediate product increases uniformly, or is simply accelerated, and its simultaneous is half its successive measure: the mediate product is duply [doubly] accelerated, and its simultaneous is one third its suc-

cessive measure; the bimediate product is triply accelerated, and its simultaneous is one fourth its successive measure; and according to the same law down to the product of the order zero, which closes the genesis by annihilating the successive measure.

In the tablet, under the two semi-units of time $\frac{1}{2}'.1'_{,}$ and $\frac{1}{2}''.1'_{,}$, any coefficient expresses the amount of its term, considered as an *effect* produced in that *semi-unit* of time; while it also expresses the value of its term considered as a *cause*, to be measured by the effect it would produce in a *unit* of time. As all the increments of the same order are the same number of genetical steps below the *independent* primitive generator $1\,\phi^{\text{v}}$, the same factor of acceleration will appear in the coefficient of each; but as the different increments in the time $\frac{1}{2}''.1'_{,}$ arise from different *dependent* constant generators, their rate of acceleration is modified accordingly.

The triply accelerated increment $\frac{4}{8}\,\phi_{1}''$ produces the quadruply accelerated effect $4\,.\,\frac{5}{16}\,\phi'$ in the time $\frac{1}{2}''.\,1'_{,}$, and one fourth of that amount (successive measure) in the time $\frac{1}{2}'.\,1'_{,}$ of its own genesis: the increment $\frac{12}{8}\,\phi''$, produced by $\frac{3}{4}\,\phi_{1}'''$ constant during $\frac{1}{2}''.\,1'_{,}$, is simply accelerated by means of this last-mentioned increment, while yet it is also triply accelerated under the primitive generator $1\,\phi^{\cdot}$, and therefore produces $\frac{1}{2}\,.\,\frac{12}{16}\,.\,5\,\phi' = \frac{30}{16}\,\phi'$ in that time; and the increment $\frac{1}{2}\,.\,\frac{24}{8}\,\phi''$, produced by $\frac{6}{4}\,\phi'''$ (which is simply accelerated, being produced by $\frac{2}{2}\,\phi_{1}^{\text{IV}}$ constant) in the time $\frac{1}{2}''.\,1'_{,}$, is doubly accelerated under the dependent constant generator $1\,\phi_{1}^{\text{IV}}$, and at the same time triply accelerated under the independent constant generator $1\,\phi^{\text{v}}$: the last-named acceleration has operated during the time $\frac{1}{2}'.\,1'_{,}$ through the increment $\frac{2}{2}\,\phi_{1}^{\text{IV}}$, and the former operates in the time $\frac{1}{2}''.\,1'_{,}$ through $2\,.\,\frac{3}{4}\,\phi'''$ and $\frac{2}{2}\,.\,\frac{12}{8}\,\phi''$, and combination gives the amount $\frac{1}{2}\,.\,\frac{1}{3}\,.\,2\,.\,3\,.\,4\,.\,5\,.\,\frac{1}{16}\,\phi' = \frac{20}{16}\,\phi'$ in the time $\frac{1}{2}''.\,1'_{,}$.

(12.) The determination of the values of $m, m', m'', m'''$ establishes the successive series of generating powers $1\,\phi^{\text{v}}, 2\,\phi^{\text{IV}}, 3\,\phi''', 4\,\phi''$, $5\,\phi'$, $1\,\phi^{0}$, for the unit of time $1'_{,}$; and now it is easy to deduce their measures for the time $x\,1_{,}$. Recollecting that each preceding term generates the succeeding one during the time of its own genesis, and will generate twice, thrice, etc. that amount during the equal time afterwards, we say that

The constant primitive $1\,\phi^{\text{v}}$ of the fifth order generates uniformly $2\,\phi^{\text{IV}}$ in the unit of time $1_{,}$, and therefore $2\,x\,\phi^{\text{IV}}$ in the time $x\,1_{,}$.

The immediately generated power of the fourth order $2\,x\,\phi^{\text{IV}}$, become constant at the expiration of the time $x\,1_t$, generates $2\,.\,3\,x^2\,\phi'''$ in the subsequent time $x\,1_t$, and therefore $3\,x^2\,\phi'''$ in the time $x\,1_t$ of its own genesis.

The mediately generated power of the third order $3\,x^2\,\phi'''$, constant at the expiration of the time $x\,1_t$, generates $3\,.\,4\,x^3\,\phi''$ in the subsequent time $x\,1_t$, and therefore $4\,x^3\,\phi''$ in the time $x\,1_t$ of its own genesis.

The bimediately generated power of the second order $4\,x^3\,\phi''$, become constant at the expiration of the time $x\,1_t$, generates $4\,.\,5\,x^4\,\phi'$ in the subsequent time $x\,1_t$, and therefore $5\,x^4\,\phi'$ in the time $x\,1_t$ of its own genesis.

The trimediately generated power of the first order $5\,x^4\,\phi'$, become constant at the expiration of the time $x\,1_t$, would generate $5\,x^5\,\phi^0$ in the subsequent time $x\,1_t$, and therefore actually does generate $1\,x^5\,\phi^0$ in the time $x\,1_t$ of its own genesis.

The successive series for the time $x\,1_t$ is therefore $1\,\phi^{\text{V}}$, $2\,x\,\phi^{\text{IV}}$, $3\,x^2\,\phi'''$, $4\,x^3\,\phi''$, $5\,x^4\,\phi'$, $1\,x^5\,\phi^0$; and it is evident, without further showing, that the corresponding simultaneous series is $1\,\phi^{\text{V}}$, $1\,x\,\phi^{\text{IV}}$, $1\,x^2\,\phi'''$, $1\,x^3\,\phi''$, $1\,x^4\,\phi'$, $1\,x^5\,\phi^0$.

The successive series of powers being simultaneously in existence at the expiration of the time $x\,1_t$, it is finally necessary to investigate their complete result for the additional time $h\,1_t$, that is, for the whole time $(x+h)\,1_t$.

The *primitive* $1\,\phi^{\text{V}}$, having generated the final result $1\,x^5\,\phi^0$ in the past time $x\,1_t$, will generate the final result $1\,h^5\,\phi^0$ in the future time $h\,1_t$.

The *immediate* $2\,x\,\phi^{\text{IV}}$, generated in the past time $x\,1_t$, and become a constant generator, will generate $2\,.\,3\,x\,h\,\phi'''$ in the future time $h\,1_t$; which $2\,.\,3\,x\,h\,\phi'''$ would generate $2\,.\,3\,.\,4\,x\,h^2\,\phi''$ in a subsequent time $h\,1_t$, and therefore actually does generate $\frac{2\,.\,3\,.\,4}{1\,.\,2}\,x\,h^2\,\phi''$ in the time $h\,1_t$ of its own genesis: this $3\,.\,4\,x\,h^2\,\phi''$ would generate $3\,.\,4\,.\,5\,x\,h^3\,\phi'$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{3\,.\,4\,.\,5}{3}\,x\,h^3\,\phi'$ in the time $h\,1_t$ of its own genesis; and this $4\,.\,5\,x\,h^3\,\phi'$ would generate $4\,.\,5\,x\,h^4\,\phi^0$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{4\,.\,5}{4}\,x\,h^4\,\phi^0$ in the time $h\,1_t$ of its own genesis.

The *mediate* $3\,x^2\,\phi'''$, generated in the past time $x\,1_t$, and become a constant generator, will generate $3.4\,x^2\,h\,\phi''$ in the future time $h\,1_t$; which $3.4\,x^2\,h\,\phi''$ would generate $3.4.5\,x^2\,h^2\,\phi'$ in a subsequent time $h\,1_t$, and therefore actually does generate $\frac{3.4.5}{1.2}\,x^2\,h^2\,\phi'$ in the time $h\,1_t$ of its own genesis; and this $\frac{3.4.5}{1.2}\,x^2\,h^2\,\phi'$ would generate $\frac{3.4.5}{1.2}\,x^2\,h^3\,\phi^0$ in the subsequent time $h\,1_t$, and therefore does generate $\frac{3.4.5}{1.2.3}\,x^2\,h^3\,\phi^0$ in the time $h\,1_t$ of its own genesis.

The *bimediate* $4\,x^3\,\phi''$, generated in the past time $x\,1_t$, and become a constant generator, will generate $4.5\,x^3\,h\,\phi'$ in the future time $h\,1_t$; while $4.5\,x^3\,h\,\phi'$ would generate $4.5\,x^3\,h^2\,\phi^0$ in the subsequent time $h\,1_t$, and therefore actually does generate $\frac{4.5}{1.2}\,x^3\,h^2$ in the time of its own genesis in $h\,1_t$.

The *trimediate* $5\,x^4\,\phi'$, generated in the past time $x\,1_t$, and become a constant generator, will generate $5\,x^4\,h\,\phi^0$ in the future time $h\,1_t$.

The *quatrimediate* $1\,x^5\,\phi^0$, generated in the past time $x\,1_t$, is a non-generator; and the final results make up the tablet:

$x\,1_t$: $\qquad\qquad\qquad\qquad h\,1_t$.

$$1\,\phi^{\mathrm{v}}\ ;\ \overbrace{\frac{1.2}{1}\,h\,\phi^{\mathrm{iv}},\ \frac{1.2.3}{1.2}\,h^2\,\phi''',\ \frac{1.2.3.4}{1.2.3}\,h^3\,\phi'',\ \frac{1.2.3.4.5}{1.2.3.4}\,h^4\,\phi',}$$
$$\frac{1.2.3.4.5.1}{1.2.3.4.5}\,h^5\,\phi^0.$$

$$2\,x\,\phi^{\mathrm{iv}}\ ;\ \frac{2.3}{1}\,x\,h\,\phi''',\ \frac{2.3.4}{1.2}\,x\,h^2\,\phi'',\ \frac{2.3.4.5}{1.2.3}\,x\,h^3\,\phi',$$
$$\frac{2.3.4.5.1}{1.2.3.4}\,x\,h^4\,\phi^0.$$

$$3\,x^2\,\phi'''\ ;\ \frac{3.4}{1}\,x^2\,h\,\phi'',\ \frac{3.4.5}{1.2}\,x^2\,h^2\,\phi',\ \frac{3.4.5.1}{1.2.3}\,x^2\,h^3\,\phi^0.$$

$$4\,x^3\,\phi''\ ;\ \frac{4.5}{1}\,x^3\,h\,\phi',\ \frac{4.5.1}{1.2}\,x^3\,h^2\,\phi^0.$$

$$5\,x^4\,\phi'\ ;\ \frac{5.1}{1}\,x^4\,h\,\phi^0.$$

$$1\,x^5\,\phi^0.$$

The final result is

$$(1\,x^5+5\,x^4\,h+10\,x^3\,h^2+10\,x^2\,h^3+5\,x\,h^4+1\,h^5)\,\phi^0=(x+h)^5\,\phi^0,$$

for the time $(x+h)\,1_t$. If $x=h=1$, the series expresses the development of $(1+1)^5\,\phi^0 = 2^5\,\phi^0 = 32\,\phi^0$ for the time $2\,.\,1_t$.

(13.) To pass from the development of $(x+h)^5$ to that of $(x-h)^5$, all the genetical operations during the time $h\,1_t$ must be reversed, or performed in the opposite direction in space; whence the tablet becomes

$$x\,1_t : \qquad \overbrace{\qquad\qquad\qquad\qquad h\,1_t. \qquad\qquad\qquad\qquad}$$

$$1\,\phi^{v}\ ; -\frac{1.2}{1}\,h\,\phi^{\text{IV}}, +\frac{1.2.3}{1.2}\,h^2\,\phi''', -\frac{1.2.3.4}{1.2.3}\,h^3\,\phi'', + \frac{1.2.3.4.5}{1.2.3.4}\,h^4\,\phi', -\frac{1.2.3.4.5.1}{1.2.3.4.5}\,h^5\,\phi^0 = -1\,h^5\,\phi^0.$$

$$2\,x\,\phi^{\text{IV}}\ ; -\frac{2.3}{1}\,x\,h\,\phi''', +\frac{2.3.4}{1.2}\,x\,h^2\,\phi'', -\frac{2.3.4.5}{1.2.3}\,x\,h^3\,\phi', + \frac{2.3.4.5.1}{1.2.3.4}\,x\,h^4\,\phi^0 = +5\,x\,h^4\,\phi^0.$$

$$3\,x^2\,\phi'''\ ; -\frac{3.4}{1}\,x^2\,h\,\phi'', +\frac{3.4.5}{1.2}\,x^2\,h^2\,\phi', -\frac{3.4.5.1}{1.2.3}\,x^2\,h^3\,\phi^0 = -10\,x^2\,h^3\,\phi^0.$$

$$4\,x^3\,\phi''\ ; -\frac{4.5}{1}\,x^3\,h\,\phi', +\frac{4.5.1}{1.2}\,x^3\,h^2\,\phi^0 = +10\,x^3\,h^2\,\phi^0.$$

$$5\,x^4\,\phi'\ ; -\frac{5.1}{1}\,x^4\,h\,\phi^0 = -5\,x^4\,h\,\phi^0.$$

$$1\,x^5\,\phi^0.$$

The final result is

$$(1\,x^5 - 5\,x^4\,h + 10\,x^3\,h^2 - 10\,x^2\,h^3 + 5\,x\,h^4 - 1\,h^5)\,\phi^0 = (x-h)^5\,\phi^0,$$

for the time $(x-h)\,1_t$. If $x=h=1$, the series expresses the development of $(1-1)^5 = 0$ for the time $(1-1)\,1_t$.

## 3. Vital Statistics. By E. B. Elliott of Boston.

*A. Tables of Prussian Mortality, interpolated for Annual Intervals of Age; accompanied with Formulæ and Process for Construction.*

*B. Discussion of Certain Methods for converting Ratios of Deaths to Population, within given Intervals of Age, into the Logarithm of the Probability that one living at the Earlier Age will attain the Later; with Illustrations from English and Prussian Data.*

*C. Process for deducing accurate Average Duration of Life, present Value of Life-Annuities, and other useful Tables involving Life-Contingencies, from Returns of Population and Deaths, without the Intervention of a General Interpolation.*

The mortality and accompanying tables, to which the attention of the Association is called, comprise portions of a series of tables that have been and are being prepared, for the New England Mutual Life Insurance Company of Boston, from official returns of the British, Swedish, Prussian, and Belgian governments, and from such reliable American statistics as are obtainable.

In several of the United States of America the decennial enumeration of the numbers and ages of the living effected for the General Government have been quite accurate and reliable, while the only official *mortality* returns (viz. those ordered in connection with the last census, 1850) are inaccurate and deficient. In Massachusetts, since its Registration Act of 1849, certain districts have furnished valuable and satisfactory information respecting the numbers and ages of the dying; but from the published abstracts it has been impossible to separate imperfect from reliable data. In the yet unpublished abstracts of the returns for 1855 an improvement is being effected, under the direction of the present Secretary of State, which, although augmenting somewhat the expense, will afford fit material for the construction of a Life-Table that shall satisfactorily represent the rates of mortality prevailing among the inhabitants of the larger part of the Commonwealth.

The leading paper (A) presents a new Life-Table, complete for annual intervals of age, and calculated from over a million (1,197,407)

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of observations regarding the ages of the dying, in a population of fifteen millions (14,928,501), and in a community where observations on vital statistics, for many years, are believed to have been made with care and accuracy. It adds *one* to the very limited list of National Life-Tables.

The remaining papers (B and C) are devoted to the discussion of certain methods for converting rates of mortality for different intervals of age into probability of living; and to the presentation of *abridged methods* for calculating, at certain ages, accurate tables of practical value, involving life-contingencies, accompanied with simple rules for determining any required value intermediate.

### A. Tables of Prussian Mortality, interpolated for Annual Intervals of Age; accompanied with Formulæ and Process for Construction.

The data from which the following tables have been calculated were obtained from documents sent by Mr. Hoffman of Berlin to the English Ministry of Foreign Affairs, and published in the Sixth Annual Report of the Registrar-General in England.

Population of Prussia, Civil and Military (exclusive of Neufchatel).*

At the end of the year 1834, 13,509,927.
" " 1837, 14,098,125.
" " 1840, 14,928,501.

The documents above mentioned give no statistics of immigration or emigration.

The increase of population during the three years 1838, '39, '40, was 830,376.

The excess of births over deaths during the same three years was 486,937.

Leaving 343,439, which is 41.36 per cent of the total increase of population, unaccounted for by excess of births over deaths.

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* "The population of Neufchatel, not included in the above, was 59,448 in 1837, 52,223 in 1825."

POPULATION OF PRUSSIA AT THE END OF THE YEAR 1840, CLASSED ACCORDING TO AGE AND SEX.

| Ages. | Males. | Females. | Males. | Females. | Ages. |
| --- | --- | --- | --- | --- | --- |
| 0 - 5 | 1,134,413 | 1,114,871 | | | |
| 5 - 7 | 370,740 | 336,429 | 2,603,699 | 2,550,022 | 0 - 14 |
| 7 - 14 | 1,098,546 | 1,068,722 | | | |
| 14 - 16 | 344,179 | 331,039 | | | 14 - 16 |
| 16 - 20 | 586,059 | | | | |
| 20 - 25 | 692,704 | | | | |
| 25 - 32 | 777,183 | | 3,238,434 | 3,253,643 | 16 - 45 |
| 32 - 39 | 646,122 | | | | |
| 39 - 45 | 536,366 | | | | |
| 45 - 60 | 816,726 | 881,280 | | | 45 - 60 |
| 60 and upwards, | 445,544 | 463,935 | | | 60 and upwards. |
| All Ages, | 7,448,582 | 7,479,919 | | | |

Assuming the distribution of the (3,253,643) females for the several intervals between the ages 16 and 45 to be proportioned to the distribution of (3,238,434) the corresponding number of males, we have

| Ages. | Females. |
| --- | --- |
| 16 - 20 | 588,812 |
| 20 - 25 | 695,957 |
| 25 - 32 | 780,833 |
| 32 - 39 | 649,156 |
| 39 - 45 | 538,885 |
| Total, 16 - 45 | 3,253,643 |

Hence the following

NUMBERS AND AGES OF THE POPULATION OF PRUSSIA AT THE END OF THE YEAR 1840.

| Ages. | Persons. |
| --- | --- |
| 0 - 5 | 2,249.284 |
| 5 - 7 | 737,169 |
| 7 - 14 | 2,167,268 |
| 14 - 16 | 675,218 |
| 16 - 20 | 1,174,871 |
| 20 - 25 | 1,388,661 |
| 25 - 32 | 1,558,016 |
| 32 - 39 | 1,295.278 |
| 39 - 45 | 1,075,251 |
| 45 - 60 | 1,698,006 |
| 60 and upwards, | 909,479 |
| All Ages, | 14,928,501 |

We wish to distribute the population from ages 25 to 45, from 45 to

60, and from 60 upwards in quinquennial or decennial periods, to correspond with the ages of the dying as presented in the mortality returns.

We first determine the quinquennial distribution between ages 25 and 45.

Let $P_{x/y}$ represent the population between ages $x$ and $y$, or the numbers living under age $y$, *less* the numbers living under age $x$.

Then $P_{16/20} = 1,174,871$
$P_{16/25} = 2,563,532$
$P_{16/32} = 4,121,548$
$P_{16/39} = 5,416,826$
$P_{16/45} = 6,492,077$
$P_{16/60} = 8,190,083$

$$\text{Assume } P_{16/x} = P_{16/a}\frac{x-b\,.\,x-c}{a-b\,.\,a-c} + P_{16/b}\frac{x-a\,.\,x-c}{b-a\,.\,b-c} + P_{16/c}\frac{x-a\,.\,x-b}{c-a\,.\,c-b}$$

Let $a = 20$, $b = 25$, $c = 32$; then will $P_{16/30} = 3,722,366.$
Let $a = 25$, $b = 32$, $c = 39$; then will $P_{16/30} = 3,703,211,$ and $P_{16/35} = 4,708,839.$
Let $a = 32$, $b = 39$, $c = 45$; then will $P_{16/35} = 4,682,050,$ and $P_{16/40} = 5,598,277.$
Let $a = 39$, $b = 45$, $c = 60$; then will $P_{16/40} = 5,611,751.$

Taking the arithmetical mean of the above duplicate results, we have

$P_{16/30} = 3,712,789$
$P_{16/35} = 4,695,445$
$P_{16/40} = 5,605,014$

Hence $P_{25/30} = 1,149,257$
$P_{30/35} = 982,656$
$P_{35/40} = 909,569$
$P_{40/45} = 887,063$

which results cannot vary materially from the actual distribution.

The following Table gives the distribution of the population of Prussia between ages 45 and 60 (1,698,006); and of the population from age 60 upwards, according to the corresponding proportional distribution of the numbers of the population of the Northwestern Division of England (the Eighth of the eleven Districts into which England and Wales are divided in the Reports of the Registrar-General).

| Ages. | Distribution of Prussian Population over age 45. |
|---|---|
| 45 - 55 | 1,257,322 |
| 55 - 60 | 440,684 |
| 60 - 65 | 353,657 |
| 65 - 75 | 398,925 |
| 75 - 85 | 137,188 |
| 85 - 95 | 18,638 |
| 95 and over, | 1,026 |
| 45 and over, | 2,607,485 |

NUMBERS AND AGES OF THE POPULATION OF THE NORTHWESTERN DIVISION (ENG.) IN 1841, ACCORDING TO WHICH THE ABOVE DISTRIBUTION WAS MADE. — (9th Rep. Reg.-Gen.)

| Ages. | Northwestern Division (Eng.), 1841. Numbers and Ages of the Living above Age 45. |
|---|---|
| 45 - 55 | 151,064 |
| 55 - 60 | 52,947 |
| 60 - 65 | 39,656 |
| 65 - 75 | 44,732 |
| 75 - 85 | 15,383 |
| 85 - 95 | 2,095 |
| 95 and over, | 115 |
| 45 and over, | 305,992 |

The numbers living above age 15 in the Northwestern Division (England) were grouped, with reference to age, only in decennial classes.

By assuming the algebraic equation,

$$P_{55/x} = P_{55/45} \cdot \frac{x-55 \,.\, x-65 \,.\, x-75}{45-55 \,.\, 45-65 \,.\, 45-75}$$
$$+ P_{55/65} \cdot \frac{x-45 \,.\, x-55 \,.\, x-75}{65-45 \,.\, 65-55 \,.\, 65-75}$$
$$+ P_{55/75} \cdot \frac{x-45 \,.\, x-55 \,.\, x-65}{75-45 \,.\, 75-55 \,.\, 75-65}$$

a close approximation to the probable number of persons living between ages 55 and 60 (52,947) and between ages 60 and 65 (39,656) resulted.

$P_{55/x}$ represents the number of persons reported living under age $x$, *less* the number living under age 55.

We remark that $P_{55/45}$ is essentially negative.

The population of the Division, as returned for the night of June 6-7, 1841, was two millions (2,098,820), being one eighth of the entire population of England and Wales (15,914,148) at that date. The counties of Cheshire and Lancashire constitute this Division. The latter county includes the densely populous and unhealthy district of Liverpool.

The ratios of deaths to population for the intervals from age 45 to 60, and from age 60 upwards, more closely approximated the corresponding ratios for Prussia, than did those of any other large community concerning which reliable population and mortality statistics were to be obtained.

TABLE COMPARING RATIOS OF THE ANNUAL NUMBER OF DEATHS TO THE NUMBERS LIVING IN CERTAIN COMMUNITIES FROM AGE 45 TO 60, AND FROM AGE 60 TO EXTREME OLD AGE.

| | Ages 45 - 60. | Ages 60 and upwards. |
|---|---|---|
| *Prussia.* | | |
| Deaths, 1839, '40, '41, / Population, 1840, . . . . . | .024 | .088 |
| *Northwestern Division (England).* | | |
| Deaths, seven years, 1838 - 44, / Population, middle, 1841, . . | .023 | .079+ |
| *Sweden.* | | |
| Deaths, twenty years, 1821 - 40, / Population, mean of 1820, '30, '40, . . | .021 | .079— |
| *Belgium.* | | |
| Deaths, nine years, 1842 - 50, / Population, October 15, 1856, . . . | .020 | .073 |
| *England and Wales.* | | |
| 1841, . . . . . . . . . | .019 | .069 |

A comparison of the distribution of the numbers of the living in Prussia in these intervals of age according to that of the Northwestern Division (Eng.), with a distribution of the same numbers according to the mean of the corresponding distribution of equal numbers of the populations of England in 1841 and of Belgium in 1846, would give the following results.

DISTRIBUTION OF THE POPULATION OF PRUSSIA ACCORDING TO

| Ages. | The Mean of Equal Numbers in England and Belgium. | The Northwestern Division (England). |
|---|---|---|
| 45 - 55 | 1,285,567 | 1,257,322 |
| 55 - 60 | 412,439 | 440,684 |
| 45 - 60 | 1,698,006 | 1,698,006 |
| 60 - 65 | 330,425 | 353,657 |
| 65 - 75 | 398,646 | 398,925 |
| 75 - 85 | 155,077 | 137,188 |
| 85 and over, | 25,331 | 19,709 |
| 60 and over, | 909,479 | 909,479 |
| 45 and over, | 2,607,485 | 2,607,485 |

The distribution according to the English and Belgian facts would give larger numbers after about age 75, in the resulting Life-Table.

The distribution according to that of the Northwestern Division was adopted as the best representation of the probable corresponding distribution of the population of Prussia, within the intervals of age above mentioned. Hence the following Table.

## DEATHS, POPULATION, MORTALITY, AND LOGARITHMS OF THE PROBABILITY OF LIVING IN PRUSSIA.

*The Numbers of the Living between ages* 45 *and* 60, *and from* 60 *to extreme old age are distributed according to corresponding proportional distributions of the numbers of the population of the Counties of Cheshire and Lancashire* (*Northwestern Division*), *in England, in* 1841.

| | DEATHS. | POPULATION. | MORTALITY. | LOGARITHMS OF PROBABILITIES OF SURVIVING EACH INTERVAL. | |
|---|---|---|---|---|---|
| | Aggregate Numbers and Ages of the Dying during the Three Years 1839, '40, '41. | Numbers and Ages of the Living at the End of the Year 1840. | Ratios of the Average Annual Numbers of the Dying during the Three Years 1839, '40, '41, to the Numbers of the Living computed with reference to the Middle of 1840. | Duplicate Values, each deduced from two consecutive Ratios in the Column of Mortality. | Values derived from Comparison of the Duplicates. |
| Ages. $x, y$. | $D_{0/y} - D_{0/x}$ | $P_{0/y} - P_{0/x}$ | $\frac{D_{x/y}}{P_{x/y}} \cdot C$ | $\lambda p_{0/y} - \lambda p_{0/x}$ | |
| | $D_{x/y}$ | $P_{x/y}$ | $M_{x/y}$ | $\lambda p_{x/y}$ | |
| 0 - 1 | 310,527 | | | | |
| 1 - 3 | 162,356 | 2,249,284 | .0802238 | | |
| 3 - 5 | 62,734 | | | | |
| 5 - 7 | 33,272 | 737,169 | .0152056 | —.013106<br>—.013201 | —.013155 |
| 7 - 14 | 27,156 | 2,167,268 | .0077790 | —.023480<br>—.023628 | —.023557 |
| 14 - 20 | 22,887 | 1,850,089 | .0062978 | —.016399<br>—.016432 | —.016416 |
| 20 - 25 | 34,585 | 1,388,661 | .0089397 | —.019433<br>—.019418 | —.019425 |
| 25 - 30 | 36,849 | 1,149,257 | .0096939 | —.021057<br>—.021059 | —.021058 |
| 30 - 35 | 31,594 | 982,656 | .0108317 | —.023533<br>—.023542 | —.023537 |
| 35 - 40 | 35,579 | 909,569 | .0131780 | —.028646<br>—.028630 | —.028637 |
| 40 - 45 | 38,094 | 887,063 | .0144675 | —.031434<br>—.031464 | —.031449 |
| 45 - 55 | 78,503 | 1,257,322 | .0210345 | —.092155<br>—.092527 | —.092322 |
| 55 - 60 | 46,704 | 440,684 | .0357042 | —.077947<br>—.078021 | —.077981 |
| 60 - 65 | 58,576 | 353,657 | .0557995 | —.122543<br>—.121891 | —.122189 |
| 65 - 75 | 107,653 | 398,925 | .0909134 | —.424020<br>—.408584 | —.415608 |
| 75 - 85 | 61,697 | 137,188 | .1515098 | —.716433<br>—.730677 | —.722021 |
| 85 and upwards | 15,572 | 19,709 | .2661784 | | |
| Total, | 1,197,407 | 14,928,501 | | | |

$$C = \tfrac{1}{3} \cdot \frac{14928501}{14770727}$$

14928501 = Population of Prussia, as returned for the end of the year 1840.

14770727 = Population of Prussia, estimated for the middle of the year 1840, from the numbers returned as living at the end of 1834, 1837, and 1840.

It will be observed that the values derived from comparison of the duplicate logarithms, and which have been adopted in constructing the Interpolated and other Tables, are not in all cases arithmetical means. The difference is of little moment, but there is no sufficient reason for preferring the former.

LOGARITHMS OF THE PROBABILITY OF SURVIVING,

*Computed from the Returns of the Numbers of the Living under Age* 5; *and of the Numbers of the Dying annually under* 1 *Year of Age, over* 1 *and under* 3, *over* 3 *and under* 5.

| Ages. | $\lambda\, P'_{x/y}$. |
|---|---|
| 0 – 1 | —.082920 |
| 1 – 3 | —.051670 |
| 3 – 5 | —.022522 |

The successive addition of the logarithms of the probabilities of surviving the consecutive intervals of age to 5.001688, the logarithm assumed for the proportional numbers born alive, gives the following

TABLE OF THE LOGARITHMS OF THE PROPORTIONS, AND THE PROPORTIONS OF PERSONS BORN ALIVE AND SURVIVING CERTAIN AGES IN PRUSSIA, ACCORDING TO THE CALCULATED LAW OF MORTALITY.

*Deaths*, 1839, '40, '41.
*Population computed with reference to middle of* 1840.
*Distribution of Population above Age* 45, *Northwestern Division* (*Eng.*).

| Age. | Survivors. | |
|---|---|---|
| | Logarithms. | Persons. |
| | $\lambda\, L_x$ | $L_x$ |
| 0 | 5.001688 | 100,389 |
| 1 | 4.918768 | 82,941 |
| 3 | 4.867098 | 73,637 |
| 5 | 4.844576 | 69,916 |
| 14 | 4.807864 | 64,249 |
| 25 | 4.772023 | 59,159 |
| 35 | 4.727428 | 53,386 |
| 45 | 4.667342 | 46,488 |
| 55 | 4.575020 | 37,585 |
| 65 | 4.374850 | 23,706 |
| 75 | 3.959242 | 9,104.2 |
| 85 | 3.237221 | 1,726.7 |
| 95 | 1.982879 | 96.1 |
| 105 | —1.803755 | .636 |

The values opposite ages 95 and 105 were computed from the logarithms of the numbers surviving at ages 65, 75, and 85, by the exponential formula,

$$\lambda L_x = \Phi_x = \Phi_{65} + (\Phi_{75} - \Phi_{65}) \frac{q^{x-65} - 1}{q^{75-65} - 1};$$

in which

$$q^{75-65} \text{ (or } q^{10}) = \frac{\Phi_{85} - \Phi_{75}}{\Phi_{75} - \Phi_{65}}.$$

These values were adopted as bases for the construction of the accompanying Life-Table *interpolated* for annual intervals of age; and also for computing by *abridged methods* certain practical life-contingency tables.

Before presenting this table and these methods, we will state some of the principles which underlie, and indicate the process by which ratios of the numbers of the dying to the numbers of the living, during the several intervals of age, have been converted into logarithms of the probabilities that one living at the earlier age will attain the later.

Whenever, in any community, the intensity of mortality at each age, or the ratio of the numbers momentarily dying during each *minute* interval of age to the numbers then living within the same interval, has been *constant* for a period of time equal to the difference between the specified age and the extreme of old age, an *invariable law of mortality* is said to prevail in that community.

The law of human mortality is seldom strictly invariable. It fluctuates within *certain limits*, not only with different communities and localities, but in the same community during successive periods, and in the same localities. The habits, occupations, and social condition of the members of the community remaining unchanged, the larger their numbers the *narrower* these limits. It is within the province of the vital statistician to determine, not merely an average of the rates of mortality prevailing in a community, but also the sensible limits within which the rates fluctuate.

Our present inquiries have reference to the determination of a law of mortality which shall satisfactorily represent the average of the rates prevailing among the inhabitants of a populous state, with fixed geographical boundaries; and in which the numbers of the inhabitants vary with births and with deaths, with immigration and with emigration.

If, in a large community, varying with births, deaths, and migrations, but in which the numbers of the population have not been subject to sudden and irregular change, the number of the dying during a given year or period of time between ages not very remote be divided by the number of the living between the same ages at the middle of that period of time, the quotient resulting from the division has generally been assumed closely to approximate the quotient that would have resulted had the numbers of the population within the limits of these ages been *stationary*; that is, assuming an invariable law of mortality, had the numbers of the population for each minute interval of age within the limits of these ages remained constant during that period, and unaffected by either immigration or emigration.

The errors involved in this assumption are of small moment compared with probable errors of observation, and vanish when the intervals of age are taken exceedingly minute, and where the excess or deficiency of the deaths in the former half of the period of time, with reference to half the deaths of the entire period, is exactly counterbalanced by a corresponding deficiency or excess of the deaths in the latter half of that period of time.

We adopt this hypothesis, and assume that each of the ratios in the column headed Mortality is identical with that which would have resulted had the population of Prussia within the limits of the ages been stationary for a period of years equal to the specified interval; and we also assume the accuracy of the Prussian mortality and population returns.

From these ratios we now proceed to determine duplicate logarithms of the probability that one surviving the earlier age in each interval will attain the later.

Let $P_{0/x}$ = the number living under age $x$, in a stationary population, in which the same law of mortality prevails as in Prussia.

$D_{0/x}$ = the number of annual deaths under age $x$ in the stationary population.

$l_0$ = the number born alive each *moment of time*, in the stationary population.

$l_x$ = the number surviving $x$ years, out of $(l_0)$ the momentary number of births.

$p_{a/b} = \frac{l_b}{l_a}$ = the probability that one surviving the earlier age ($a$) will attain the later ($b$).

$\delta_{0/x} = l_0 - l_x$ = the number dying in $x$ years out of ($l_0$) the momentary number of births.

In a stationary population

$$D_{0/x} = \frac{\delta_{0/x}}{dx},$$

and

$$d\,P_{0/x} = l_x;$$

therefore,

$$P_{0/x} = \int (l_0 - \delta_{0/x}) = \frac{x \,.\, l_0}{dx} - \int \delta_{0/x}.$$

But $M_{a/b}$, the ratio of the average annual number of deaths in Prussia between ages $a$ and $b$ to the number of the living between these ages, computed with reference to the middle of the period in which the deaths occur, equals $\frac{D_{a/b} = D_{0/b} - D_{0/a}}{P_{a/b} = P_{0/b} - P_{0/a}}$.

Assume $\delta_{0/x} = Qx + Rx^2$, $Q$ and $R$ being unknown, and independent of the variable $x$.

Then

$$D_{0/x} = \frac{Qx + Rx^2}{dx},$$

and

$$\int \delta_{0/x} = \left(Q\frac{x^2}{2} + R\frac{x^3}{3}\right)\frac{1}{dx}.$$

Hence

$$M_{a/b}\left(\text{which} = \frac{D_{a/b}}{P_{a/b}} = \frac{D_{0/b} - D_{0/a}}{P_{0/b} - P_{0/a}}\right) = \frac{Q\,\overline{b-a} + R\,\overline{b^2-a^2}}{l_0\,\overline{b-a} - Q\frac{b^2-a^2}{2} - R\frac{b^3-a^3}{3}}$$

$$= \frac{Q + R\,\overline{b+a}}{l_0 - Q\frac{b+a}{2} - R\frac{b^2+ab+a^2}{3}},$$

and

$$M_{b/c} = \frac{Q + R\,\overline{c+b}}{l_0 - Q\frac{c+b}{2} - R\frac{c^2+bc+b^2}{3}}.$$

So also,

$$\lambda p_{a/b} \text{ (which } = \lambda \frac{l_b}{l_a} = \lambda \frac{l_0 - \delta_{0/b}}{l_0 - \delta_{0/a}}\Big) = \lambda \frac{l_0 - Q b - R b^2}{l_0 - Q a - R a^2},$$

and

$$\lambda p_{b/c} = \lambda \frac{l_0 - Q c - R c^2}{l_0 - Q b - R b^2}.$$

Given $M_{a/b}$ and $M_{b/c}$, required $\lambda p_{a/b}$ and $\lambda p_{b/c}$.

First determine values for $Q$ and $R$; the values of $\lambda p_{a/b}$ and $\lambda p_{b/c}$ are then readily found.

$$Q = \frac{\gamma' M_{a/b} - \beta' M_{b/c}}{\gamma' \beta - \beta' \gamma} \cdot l_0,$$

and

$$R = \frac{\gamma M_{a/b} - \beta M_{b/c}}{\gamma \beta' - \beta \gamma'} \cdot l_0;$$

in which

$$\beta = 1 + \frac{(b + a) M_{a/b}}{2};$$

$$\beta' = b + a + \frac{(b^2 + b a + a^2) M_{a/b}}{3};$$

$$\gamma = 1 + \frac{(c + b) M_{b/c}}{2};$$

$$\gamma' = c + b + \frac{(c^2 + c b + b^2) M_{b/c}}{3}.$$

The reduction may be simplified by letting $l_0 = 1$, and by the use of addition and subtraction logarithms.

In like manner, from $M_{b/c}$ and $M_{c/d}$ obtain $\lambda p_{b/c}$ and $\lambda p_{c/d}$; and so on for all intervals of age which the returns give.

We thus obtain *duplicate* values for the logarithms of the probabilities of surviving all the intervals specified except two. For the first and the last interval we have but single values. We may, without material error, adopt for the true probability the mean of these duplicate results.

It will be observed that the conversion, in each of these cases, is made for the *entire* interval, not, as is more frequent, for the *middle*

*year* of the interval. We are thus enabled, without the intervention of a general interpolation, to compute directly the number surviving at certain ages in the resulting life-table, out of a specified number born alive.

Usually the conversion is from a *single* ratio, based upon the assumption of a uniform distribution of deaths throughout the interval. By the present method, however, the conversion is effected, taking into account the actual or variable distribution of deaths, from *three* consecutive ratios, one preceding and another following the interval. A comparison of the relative accuracy and simplicity of several methods for effecting the conversion will be given on a following page.

We now proceed to indicate methods for obtaining *probabilities of surviving from birth to ages one, three, and five.*

We have the average annual number of deaths in Prussia under the ages of one, three, and five ($D_{0/1}$, $D_{0/3}$, $D_{0/5}$), for the period of the three years 1839, '40, '41; and the population under the age of five ($P_{0/5}$) at the end of the middle year of the period (end of 1840); also the *ratio* $\left(\frac{1}{v}\right)$ of the annual increase in the number of births deduced from the numbers registered for each of the six years 1836 – 41. The average annual number of deaths for the three years 1839, '40, '41 we shall consider identical with the number of deaths for the year 1840.

From the following, it would appear that the *accurate* number of those born alive cannot be obtained directly from official reports, because of probable deficiencies in registration. If the numbers of the living and of the dying at the earlier ages have been accurately observed and returned, if the numbers at these ages have been but little affected by immigration and emigration, and if the ratio of annual increase in the number of births can be obtained, a close approximation to the actual number of those born alive may be computed.

Let $l_0$ be the number of those momentarily born alive in Prussia at the time for which the census was taken (end of 1840).

$\frac{1}{v} = \left(\frac{\text{births 1839, '40, '41}}{\text{births 1836, '37, '38}}\right)^{\frac{1}{3}} = 1.01545$, the ratio of the annual increase in the number of births estimated from those registered for each of the six years 1836 – 41.

$\lambda \frac{1}{v} = .0066586$, the logarithm of this ratio.

Let $\delta_{0/x}$ be the number that died before attaining the age of $x$ years (according to the prevailing law of mortality) out of $(l_0)$ the number born alive in Prussia during the moment of time (end of 1840) that the enumeration of the living is supposed to have been made.

$v^x \, d\,\delta_{0/x}$ will express the number of those aged $x$ years that died in Prussia during the supposed moment of enumeration.

$$\int_0^x v^x \, d\,\delta_{0/x} \int_0^1 v^x = D_{0/x},$$

the annual number of deaths in Prussia under the age of $x$ years, for the year ending with the census, i. e. for the year 1840.

$$v^x \int_0^x v^{-x} \int_0^x v^x \, d\,\delta_{0/x}$$

represents the total number that died in Prussia during the $x$ years preceding the time of the enumeration of the living, out of the numbers born alive within that period. This expression obviously equals

$$v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}.$$

$$l_0 \int_0^x v^x$$

represents the number born alive during the $x$ years preceding the time of the enumeration.

The numbers born alive within this period of $x$ years, *less* the numbers dying within the period out of the numbers born alive, obviously represent the numbers of the living at the end of the period under the age of $x$ years; immigration and emigration among those under age $x$ being considered null.

$$P_{0/x} = l_0 \int_0^x v^x - v^x \int_0^x v^{-x} \int_0^x v^x \, d\,\delta_{0/x}$$

$$= l_0 \int_0^x v^x - v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}.$$

$$l_0 \int_0^1 v^x = L_0,$$

the numbers born alive during (1840) the year immediately preceding the time of enumeration.

Hence

$$L_0 \left(= l_0 \int_0^1 v^x\right) = \left\{P_{0/x} + v^x \int_0^x v^{-x} \int_0^x v^x \, d\, \delta_{0/x}\right\} \frac{\int_0^1 v^x}{\int_0^x v^x}$$

$$= \left\{P_{0/x} + v^x \int_0^x v^{-x} \frac{D_{0/x}}{\int_0^1 v^x}\right\} \frac{\int_0^1 v^x}{\int_0^x v^x}.$$

$$d\,x \int_0^x v^x = \frac{v^x - 1}{V};$$

in which $V$ is the Napierian logarithm of $v$.

Let $x = 5$; then will

$$L_0 = \left\{ P_{0/5} + \int_0^5 \frac{v^5\, V}{v-1} \cdot \frac{D_{0/x}\, d\,x}{v^x} \right\} \frac{v-1}{v^5-1}.$$

To simplify, let

$$D'_{0/x}\, d\,x = \frac{v^{5-x}\, D_{0/x}}{\int_0^1 v^x} = \frac{v^5\, V}{v-1} \cdot \frac{D_{0/x}\, d\,x}{v^x}.$$

Then

$$L_0 = \{P_{0/x} + \int_0^5 D'_{0/x}\, d\,x\} \frac{v-1}{v^5-1}.$$

The returns give

$D_{0/1} =$ 103,509, $D_{0/3} =$ 157,628, $D_{0/5} =$ 178,539 — average annual deaths under ages one, three, and five.

$P_{0/5} =$ 2,249,284 — population under age five at the end of the year 1840.

From these, and from .0066586 $\left(= \lambda \frac{1}{v}\right)$ the logarithm of the ratio of annual increase among registered births, we find

$$D'_{0/1} = 98{,}100,$$
$$D'_{0/3} = 154{,}043,$$
$$D'_{0/5} = 179{,}912.$$

Assume

$$D'_{0/x} = D'_{0/0}\,[=0] + x\,\theta + x\,.\,\overline{x-1}\,\theta^2 + x\,.\,\overline{x-1}\,.\,\overline{x-3}\,\theta^3 + x\,.\,\overline{x-1}\,.\,\overline{x-3}\,.\,\overline{x-5}\,R$$

$$= x\,\theta + (x^2 - x)\,\theta^2 + (x^3 - 4\,x^2 + 3\,x)\,\theta^3 + (x^4 - 9\,x^3 + 23\,x^2 - 15\,x)\,R.$$

$$\int_0^x D'_{0/x}\,dx = \frac{x^2}{2}\theta + \left(\frac{x^3}{3} - \frac{x^2}{2}\right)\theta^2 + \left(\frac{x^4}{4} - \frac{4x^3}{3} + \frac{3x^2}{2}\right)\theta^3$$
$$+ \left(\frac{x^5}{5} - \frac{9x^4}{4} + \frac{23x^3}{3} - \frac{15x^2}{2}\right)R$$
$$= \frac{x^2}{2}\left\{\theta + \frac{2x-3}{3}\theta^2 + \frac{(3x-16)x+18}{6}\theta^3 + \frac{[(12x-135)x+460]x-450}{30}R\right\}.$$

$$\frac{dD'_{0/x}}{dx} = \theta + (2x-1)\theta^2 + (3x^2 - 8x + 3)\theta^3$$
$$+ (4x^3 - 27x^2 + 46x - 15)R.$$

$$\frac{d^2 D'_{0/x}}{(dx)^2} = 2\theta^2 + (6x-8)\theta^3 + (12x^2 - 54x + 46)R.$$

$\theta$, $\theta^2$, and $\theta^3$ are the *divided differences* of the values $D_{0/0}$ ($=0$), $D_{0/1}$, $D_{0/3}$, and $D_{0/5}$; and $R$ is indeterminate.

| | $\Delta$ | $\theta$ | $\Delta\theta$ | $\theta^2$ | $\Delta\theta^2$ | $\theta^3$ |
|---|---|---|---|---|---|---|
| $D'_{0/0} =$ 0 000 | | | | | | |
| | 98,100 | 98,100. | | | | |
| $D'_{0/1} =$ 98,100 | | | — 70,128.5 | — 23,376.17 | | |
| | 55,943 | 27,971.5 | | | 19,616.92 | 3,923.38 |
| $D'_{0/3} =$ 154,043 | | | — 15,037.0 | — 3,759.25 | | |
| | 25,869 | 12,934.5 | | | | |
| $D'_{0/5} =$ 179,912 | | | | | | |

We observe that the divided differences of the first order are *positive*, and that they *diminish* as the age advances.

Required for $R$ a value such that the *first* differential coefficients of the function assumed for $D'_{0/x}$ be *positive*. It would also be desirable, if possible, that the *second* differential coefficients, from birth to at least age five, be *negative*.

The latter is not possible for the entire period, with our present values for $D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$, if we assume but one arbitrary value ($R$). Our object, however, is sufficiently attained by taking, for $R$, a value such that for ages *three* and *five* the above conditions shall be observed.

That the first differential coefficients be *positive* for ages three and five, it is requisite that

$$R < 396.6$$
$$> -920.1;$$

that the second differential coefficients be *negative* for the same ages, it is requisite that

$$R > -939.8$$
$$< -520.6;$$

from which it appears that $R$ should be *negative*, and that its value be

$$\text{between } -920.1$$
$$\text{and } -520.6$$

Let $R = -700$. We now have

$$\begin{aligned} \theta &= 98{,}100 \\ \theta^2 &= -23{,}376.17 \\ \theta^3 &= 3{,}923.38 \\ R &= -700. \end{aligned}$$

Hence

$$\int_0^5 D'_{0/x}\,dx \text{ (which } = \frac{25}{2}\theta + \frac{175}{6}\theta^2 + \frac{325}{12}\theta^3 - \frac{125}{12}R) = 657{,}995.$$

$$L_0 = \left\{P_{0/5} + \int_0^5 D'_{0/x}\,dx\right\}\frac{v-1}{v^5-1};$$

in which

$$\lambda\frac{v-1}{v_5-1} = \bar{1}.3142433,$$

and

$$P_{0/5} = 2{,}249{,}284;$$

therefore,

$$L_0 = 599{,}418.$$

By the above process the probable number born alive during the year 1840 is found to have been 599,418 instead of 562,394, the average of the numbers *registered* as born alive during each of the three years 1839, '40, '41; thereby indicating an annual deficiency in the registration of 37,024, or about 6.2 per cent of the probable number born.

In the above we have supposed the numbers of the dying and of the living at early ages accurately returned. If either be represented less than truth, the resulting correction would give still larger the probable number of births. Correction for deaths that escape registration, if any, would tend to reduce the probabilities of living.

Having found $L_0$ (which equals $\frac{v-1}{V}\cdot\frac{l_0}{dx}$), the annual number of births for the year 1840, we next seek values, corresponding to intervals of age 0 - 1, 1 - 3, and 3 - 5, for $D''_{0/x}$ (which equals $\frac{v-1}{V}\cdot\frac{d_{0/x}}{dx}$), the annual number of deaths in a stationary popula-

tion in which $L_0$ is the annual number of births; or the number that must die in $x$ years, according to the law of mortality prevailing in Prussia, out of $L_0$, born alive.

$$v^x D'_{0/x} = \frac{v^5 V}{v-1} D_{0/x}$$

$$= \frac{v^5 V}{v-1} \int_0^x v^x \frac{d\,\delta_{0/x}}{dx} \cdot \frac{v-1}{V}$$

$$= \frac{v^5 V}{v-1} \int_0^x v^x\, d\,D''_{0/x}.$$

$$\therefore\ v^x\, d\,D''_{0/x} = \frac{v-1}{v^5 V} \cdot d\,(v^x D'_{0/x}).$$

But

$$d\,(v^x \cdot D'_{0/x}) = v^x \cdot d\,D'_{0/x} + D'_{0/x} \cdot d\,v^x = v^x\,(d\,D'_{0/x} + V D'_{0/x}\,d\,x);$$

$$\therefore\ d\,D''_{0/x} = (d\,D'_{0/x} + V D'_{0/x}\,d\,x)\,\frac{v-1}{v^5 V}.$$

Integrating,

$$D''_{0/x} = \frac{v-1}{v^5 V} D'_{0/x} + \frac{v-1}{v^5} \int_0^x D'_{0/x}\,d\,x.$$

$v$, $V$, $D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$ are already known; also $\theta$, $\theta^2$, and $\theta^3$, and $R$ in the expression

$$\int_0^x D'_{0/x}\,d\,x = \frac{x^2}{2}\left\{\theta + \frac{2x-3}{3}\theta^2 + \frac{(3x-16)\,x+18}{6}\theta^3 + \frac{[(12\,x-135)\,x+460]\,x-450}{30} R\right\}.$$

Substituting for $x$ values 1, 3, and 5, we have

$$\int_0^1 D'_{0/x}\,d\,x = 55{,}899,$$

$$\int_0^3 D'_{0/x}\,d\,x = 323{,}335,$$

$$\int_0^5 D'_{0/x}\,d\,x = 657{,}995.$$

Therefore,

$$D''_{0/1} = 104{,}184,$$
$$D''_{0/3} = 159{,}735,$$
$$D''_{0/5} = 181{,}955.$$

$\lambda p_{0/x}$ (the logarithm of the probability that one born alive will survive $x$ years) $= \lambda \frac{l_0 - \delta_{0/x}}{l_0} = \lambda \frac{L_0 - D''_{0/x}}{L_0}$.

Therefore,

$$\lambda p_{0/1} = \bar{1}.9170804 = \lambda .82619,$$
$$\lambda p_{0/3} = \bar{1}.8654097 = \lambda .73352,$$
$$\lambda p_{0/5} = \bar{1}.8428880 = \lambda .69645.$$

Hence of 100,000 born alive there will attain the age of

one year 82,619,
three years 73,352,
five years 69,645;

or of 100,389 born alive there will attain the age of

one year 82,941,
three years 73,637,
five years 69,916.

The latter results are those adopted in the accompanying interpolated and other tables. These tables, as first constructed, represented the probability of surviving five years from birth to be .69916, computed by a process less rigorous and satisfactory than the one just described. By assuming the same number surviving at age five (69,916) as in the original table, modification of the values for ages greater than five becomes unnecessary.

The logarithms of the numbers surviving certain ages out of 100,389 born alive may be continued for ages greater than five, by successively adding to 4.8445759 (the logarithm of the number surviving age five), the logarithms that have previously been determined for the probabilities of surviving the consecutive intervals.

The table will then be ready, either for a general interpolation of the numbers surviving each anniversary of birth, or for obtaining, by abridged methods, the accurate average duration of life, life annuities, annual premiums, single premiums, and other practical tables involving life contingencies, for certain ages, without the intervention of a general interpolation. Simple rules may also be added for computing from these periodical results any specified values intermediate.

The following is a brief method for finding *approximate* values for the probabilities of surviving the intervals from birth to ages one, three, and five, on the supposition of a probable deficiency in the registered number of births, and that the ratio between the numbers registered and the true numbers is constant.

The same interpretation of symbols is observed as in the last demonstration.

We already have

$$L_0 = l_0 \int_0^1 v^x = \frac{P_{0/5} + \int_0^5 D'_{0/x}\, d\,x}{\int_0^5 v^x} \int_0^1 v^x,$$

$$D'_{0/x}\, d\,x = \frac{v^{5-x}\, D_{0/x}}{\int_0^1 v^x},$$

and

$$D_{0/x} = \int_0^x v^x\, d\,\delta_{0/x} \int_0^1 v^x.$$

When the interval $(0-x)$ is not large, $x\, v^{\frac{x}{2}}$ is a close approximation to the value of $\int_0^x v^x\, d\,x$; hence the following approximate relations.

$$L_0 = \frac{l_0}{d\,x} v^{\frac{1}{2}} = \left\{ P_{0/5} + \int_0^5 D'_{0/x}\, d\,x \right\} \frac{v^{\frac{1}{2}}}{5\, v^{\frac{5}{2}}}.$$

$$D'_{0/x} = \frac{v^5}{v^{\frac{1}{2}}} \cdot \frac{D_{0/x}}{v^x}.$$

$$v^{\frac{1}{2}} \cdot \frac{d\,\delta_{0/x}}{d\,x} = \frac{d\,D_{0/x}}{v^x}.$$

Let us first seek an approximate value for $L_0$.

It is obvious that

$$\int_0^5 D'_{0/x}\, d\,x = \int_3^5 D'_{0/x}\, d\,x + \int_1^3 D'_{0/x}\, d\,x + \int_0^1 D'_{0/x}\, d\,x.$$

Assuming each term, in the right-hand member, to be the integral of the general term of an *equidifferent* progression, we have

$$\int_3^5 D'_{0/x}\, d\,x = \overline{5-3}\, \frac{D'_{0/5} + D'_{0/3}}{2}.$$

$$\int_1^3 D'_{0/x}\, d\,x = \overline{3-1}\, \frac{D'_{0/3} + D'_{0/1}}{2}.$$

$$\int_0^1 D'_{0/x}\, d\,x = \overline{1-0}\, \frac{D'_{0/1}}{2}.$$

Therefore,

$$\int_0^5 D'_{0/x}\, d\,x = D'_{0/5} + 2\, D'_{0/3} + \tfrac{3}{2}\, D'_{0/1}.$$

Since

$$D'_{0/x} = \frac{v^5}{v^{\frac{1}{2}}} \cdot \frac{D_{0/x}}{v^x},$$

$D'_{0/1}$, $D'_{0/3}$, and $D'_{0/5}$ equal respectively 98101, 154044, and 179913.

Therefore,

$$\int_0^5 D'_{0/x}\, d\,x = 635{,}152.$$

But

$$L_0 = \frac{P_{0/5} + \int_0^5 D'_{0/x}\, d\,x}{5\,v^2}$$

$$= \frac{2{,}249{,}284 + 635{,}152 = 2{,}884{,}436}{5\,v^2}$$

$$= 594{,}851.$$

594,851, the computed number of births for the year 1840 by this *approximate* method, is *less* by about three fourths of one per cent than 599,418, the corresponding number of births computed by the previous method.

Having found an approximate value for

$$v^{\frac{1}{2}} \,.\, \frac{l_0}{d\,x} \text{ (or } L_0\text{)},$$

we next wish approximate values for

$$v^{\frac{1}{2}} \,.\, \frac{\delta_{0/x}}{d\,x} \left(\text{or} \int_0^x \frac{d\,D_{0/x}}{v^x}\right),$$

corresponding to intervals of age 0 – 1, 0 – 3, and 0 – 5.

When the interval $b - a$ is small,

$$\int_a^b \frac{d\,D_{0/x}}{v^x} \text{ nearly equals } \frac{D_{0/b} - D_{0/a}}{v^{\frac{b+a}{2}}}, \text{ or } \frac{D_{a/b}}{v^{\frac{b+a}{2}}}.*$$

Hence the following approximations:

$$v^{\frac{1}{2}}\,\frac{\delta_{0/1}}{d\,x} = \frac{D_{0/1}}{v^{\frac{1}{2}}} = 104{,}306.$$

$$v^{\frac{1}{2}}\,\frac{\delta_{1/3}}{d\,x} = \frac{D_{1/3}}{v^2} = \ \ 55{,}804.$$

$$v^{\frac{1}{2}}\,\frac{\delta_{3/5}}{d\,x} = \frac{D_{/5}}{v^4} = \ \ 22{,}234.$$

$$\therefore\ v^{\frac{1}{2}}\,\frac{\delta_{0/1}}{d\,x} = 104{,}306.$$

$$v^{\frac{1}{2}}\,\frac{\delta_{0/3}}{d\,x} = 160{,}110.$$

$$v^{\frac{1}{2}}\,\frac{\delta_{0/5}}{d\,x} = 182{,}344.$$

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* This approximation was adopted by Dr. Farr in constructing his Austrian Life-Table. — *Rep. Reg. Gen.*

Hence

$$p_{0/1}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/1} v^1}{dx}}{L_0}) = \lambda^{-1}\bar{1}.9162709 = .82465.$$

$$p_{0/3}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/3} v^{\frac{1}{3}}}{dx}}{L_0}) = \lambda^{-1}\bar{1}.8638226 = .73084.$$

$$p_{0/5}\ (\text{which} = \frac{L_0 - \frac{\delta_{0/5} v^{\frac{1}{5}}}{dx}}{L_0}) = \lambda^{-1}\bar{1}.8410233 = .69346.$$

Then of 100,000 born alive there will be living at ages

(1) 82,456,
(3) 73,084,
(5) 69,346;

or assuming the number living at age five to be 69,916, the same as in accompanying tables, then out of 100,821 born alive there will be living at ages

(1) 83,143,
(3) 73,684,
(5) 69,916.

This table, joined with the interpolated for ages greater than five, gives for average future duration of life 36.51 years from birth, instead of 36.66, according to the values previously obtained, and adopted in the interpolated and other tables.

If we substitute 562,394, the average annual number *returned* as born alive in Prussia for a period of time (1839, '40, '41) of which the year 1840 was the middle, for 594,851, the approximate number just computed, we shall find

$$\lambda p_{0/1} = \bar{1}.9109082 = \lambda .81453,$$
$$\lambda p_{0/3} = \bar{1}.8544920 = \lambda .71531,$$
$$\lambda p_{0/5} = \bar{1}.8298000 = \lambda .67577;$$

and out of 103,461 born alive 84,272 will survive one year,

74,006 " three years,
69,916 " five years,

and the average future duration of life from birth will appear to have been 35.61 years.

A *general interpolation* of the logarithms of the proportions surviving each anniversary of birth intermediate the specified ages, gives the following.

PRUSSIAN LIFE-TABLE, CALCULATED FROM THE AGES OF THOSE DYING DURING THE THREE YEARS 1839, '40, '41; AND FROM THE AGES OF THE LIVING COMPUTED WITH REFERENCE TO THE MIDDLE OF THE YEAR 1840.

| Ages. | Logarithms: of the Numbers Born, and Living at each Age. $\lambda L_x$ | Logarithms: of the Probability, at each Age, of Living One Year. $\lambda L_{x+1} - \lambda L_x$ / $\lambda p_x$ | Differences between Consecutive Logarithms of the Probability of Living. $\lambda p_x - \lambda p_{x+1}$ / $-\Delta \lambda p_x$ | Persons: Born, and Living at each Age. $L_x$ | Persons: Dying during each Year of Age. $L_x - L_{x+1}$ / $D_x$ | Average Future Duration (or Expectation) of Life. $E_x$ |
|---|---|---|---|---|---|---|
| 0 | 5.001688 | .917080 — 1. | — 51797 | 100,389 | 17,448 | 36.66 |
| 1 | 4.918768 | .968877 | — 10576 | 82,941 | 5,736 | |
| 2 | 4.887645 | .979453 | — 7597 | 77,205 | 3,568 | |
| 3 | 4.867098 | .987050 | — 3378 | 73,637 | 2,163 | |
| 4 | 4.854148 | .990428 | — 1854 | 71,474 | 1,558 | |
| 5 | 4.844576 | .992282 | — 1678 | 69,916 | 1,232 | 47.06 |
| 6 | 4.836858 | .993960 | — 1241 | 68,684 | 948 | |
| 7 | 4.830818 | .995201 | — 886 | 67,736 | 745 | |
| 8 | 4.826019 | .996087 | — 601 | 66,991 | 601 | |
| 9 | 4.822106 | .996688 | — 381 | 66,390 | 504 | |
| 10 | 4.818794 | .997069 | — 210 | 65,886 | 443 | 44.81 |
| 11 | 4.815863 | .997279 | — 84 | 65,443 | 409 | |
| 12 | 4.813142 | .997363 | 4 | 65,034 | 393 | |
| 13 | 4.810505 | .997359 | 63 | 64,641 | 392 | |
| 14 | 4.807864 | .997296 | 99 | 64,249 | 399 | |
| 15 | 4.805160 | .997197 | 120 | 63,850 | 411 | 41.17 |
| 16 | 4.802357 | .997077 | 121 | 63,439 | 425 | |
| 17 | 4.799434 | .996956 | 123 | 63,014 | 440 | |
| 18 | 4.796390 | .996833 | 114 | 62,574 | 455 | |
| 19 | 4.793223 | .996719 | 107 | 62,119 | 468 | |
| 20 | 4.789942 | .996612 | 101 | 61,651 | 479 | 37.54 |
| 21 | 4.786554 | .996511 | 95 | 61,172 | 489 | |
| 22 | 4.783065 | .996416 | 95 | 60,683 | 499 | |
| 23 | 4.779481 | .996321 | 100 | 60,184 | 508 | |
| 24 | 4.775802 | .996221 | 106 | 59,676 | 517 | |
| 25 | 4.772023 | .996115 | 118 | 59,159 | 527 | 34.02 |
| 26 | 4.768138 | .995997 | 121 | 58,632 | 538 | |
| 27 | 4.764135 | .995876 | 125 | 58,094 | 549 | |
| 28 | 4.760011 | .995751 | 128 | 57,545 | 560 | |
| 29 | 4.755762 | .995623 | 133 | 56,985 | 571 | |
| 30 | 4.751385 | .995490 | 137 | 56,414 | 583 | 30.55 |
| 31 | 4.746875 | .995353 | 140 | 55,831 | 594 | |
| 32 | 4.742228 | .995213 | 144 | 55,237 | 606 | |
| 33 | 4.737441 | .995069 | 151 | 54,631 | 617 | |
| 34 | 4.732510 | .994918 | 153 | 54,014 | 628 | |
| 35 | 4.727428 | .994765 | 158 | 53,386 | 640 | 27.14 |
| 36 | 4.722193 | .994607 | 159 | 52,746 | 651 | |
| 37 | 4.716800 | .994448 | 161 | 52,095 | 661 | |
| 38 | 4.711248 | .994287 | 165 | 51,434 | 673 | |
| 39 | 4.705535 | .994122 | 171 | 50,761 | 682 | |
| 40 | 4.699657 | .993951 | 185 | 50,079 | 693 | 23.76 |
| 41 | 4.693608 | .993766 | 204 | 49,386 | 703 | |
| 42 | 4.687374 | .993562 | 230 | 48,683 | 717 | |
| 43 | 4.680936 | .993332 | 258 | 47,966 | 731 | |
| 44 | 4.674268 | .993074 | 291 | 47,235 | 747 | |
| 45 | 4.667342 | .992783 | 323 | 46,488 | 766 | 20.40 |
| 46 | 4.660125 | .992460 | 352 | 45,722 | 787 | |
| 47 | 4.652585 | .992108 | 391 | 44,935 | 809 | |
| 48 | 4.644693 | .991717 | 438 | 44,126 | 834 | |
| 49 | 4.636410 | .991279 | 498 | 43,292 | 860 | |
| 50 | 4.627689 | .990781 — 1. | 570 | 42,432 | 892 | 17.11 |

| Ages. | Logarithms: Of the Numbers Born, and Living at each Age. $\lambda L_x$ | Logarithms: Of the Probability, at each Age, of Living One Year. $\lambda L_{x+1} - \lambda L_x$ / $\lambda p_x$ | Differences between Consecutive Logarithms of the Probability of Living. $\lambda p_x - \lambda p_{x+1}$ / $-\Delta \lambda p_x$ | Persons: Born, and Living at each Age. $L_x$ | Persons: Dying during each Year of Age. $L_x - L_{x+1}$ / $D_x$ | Average Future Duration (or Expectation) of Life. $E_x$ |
|---|---|---|---|---|---|---|
| 51 | 4.618470 | .990211 — 1. | 651 | 41,540 | 925 | |
| 52 | 4.608681 | .989560 | 745 | 40,615 | 965 | |
| 53 | 4.598241 | .988815 | 851 | 39,650 | 1,008 | |
| 54 | 4.587056 | .987964 | 970 | 38,642 | 1,057 | |
| 55 | 4.575020 | .986994 | 1101 | 37,585 | 1,108 | 13.98 |
| 56 | 4.562014 | .985893 | 1307 | 36,477 | 1,166 | |
| 57 | 4.547907 | .984586 | 1491 | 35,311 | 1,231 | |
| 58 | 4.532493 | .983095 | 1657 | 34,080 | 1,302 | |
| 59 | 4.515588 | .981438 | 1803 | 32,778 | 1,371 | |
| 60 | 4.497026 | .979635 | 1934 | 31,407 | 1,439 | 11.22 |
| 61 | 4.476661 | .977701 | 2042 | 29,968 | 1,500 | |
| 62 | 4.454362 | .975659 | 2137 | 28,468 | 1,551 | |
| 63 | 4.430021 | .973522 | 2215 | 26,917 | 1,592 | |
| 64 | 4.403543 | .971307 | 2275 | 25,325 | 1,619 | |
| 65 | 4.374850 | .969032 | 2323 | 23,706 | 1,632 | 9.03 |
| 66 | 4.343882 | .966709 | 2330 | 22,074 | 1,629 | |
| 67 | 4.310591 | .964379 | 2337 | 20,445 | 1,610 | |
| 68 | 4.274970 | .962042 | 2345 | 18,835 | 1,576 | |
| 69 | 4.237012 | .959697 | 2351 | 17,259 | 1,530 | |
| 70 | 4.196709 | .957346 | 2360 | 15,729 | 1,471 | 7.36 |
| 71 | 4.154055 | .954986 | 2367 | 14,258 | 1,404 | |
| 72 | 4.109041 | .952619 | 2414 | 12,854 | 1,328 | |
| 73 | 4.061660 | .950205 | 2828 | 11,526 | 1,249 | |
| 74 | 4.011865 | .947377 | 2988 | 10,277 | 1,173 | |
| 75 | 3.959242 | .944389 | 3157 | 9,104 | 1,094 | 5.97 |
| 76 | 3.903631 | .941232 | 3338 | 8,010 | 1,014 | |
| 77 | 3.844863 | .937894 | 3527 | 6,996 | 932 | |
| 78 | 3.782757 | .934367 | 3726 | 6,064 | 851 | |
| 79 | 3.717124 | .930641 | 3939 | 5,213 | 769 | |
| 80 | 3.647765 | .926702 | 4162 | 4,444 | 690 | 4.80 |
| 81 | 3.574467 | .922540 | 4399 | 3,754 | 613 | |
| 82 | 3.497007 | .918141 | 4648 | 3,141 | 540 | |
| 83 | 3.415148 | .913493 | 4913 | 2,601 | 470 | |
| 84 | 3.328641 | .908580 | 5191 | 2,131 | 404 | |
| 85 | 3.237221 | .903389 | 5485 | 1,727 | 345 | 3.82 |
| 86 | 3.140610 | .897904 | 5799 | 1,382 | 289 | |
| 87 | 3.038514 | .892105 | 6126 | 1,093 | 241 | |
| 88 | 2.930619 | .885979 | 6475 | 852 | 196 | |
| 89 | 2.816598 | .879504 | 6842 | 656 | 159 | |
| 90 | 2.696102 | .872662 | 7231 | 497 | 127 | 3.02 |
| 91 | 2.568764 | .865431 | 7641 | 370 | 98 | |
| 92 | 2.434195 | .857790 | 8076 | 272 | 76 | |
| 93 | 2.291985 | .849714 | 8534 | 196 | 57 | |
| 94 | 2.141699 | .841180 | 9019 | 139 | 43 | |
| 95 | 1.982879 | .832161 | 9530 | 96 | 31 | |
| 96 | 1.815040 | .822631 | 10072 | 65 | 22 | |
| 97 | 1.637671 | .812559 | 10644 | 43 | 15 | |
| 98 | 1.450230 | .801915 | 11248 | 28 | 10 | |
| 99 | 1 252145 | .790667 | 11887 | 18 | 7 | |
| 100 | 1.042812 | .778780 | 12562 | 11 | 4.4 | |
| 101 | 0.821592 | .766218 | 13275 | 6.6 | 2.7 | |
| 102 | 0.587810 | .752943 | 14029 | 3.9 | 1.7 | |
| 103 | 0.340753 | .738914 | 14826 | 2.2 | 1.0 | |
| 104 | 0.079667 | .724088 — 1. | | 1.2 | .6 | |
| 105 | 1.803755 | | | .6 | .6 | |

The leading features in the interpolated Life-Table for Prussia are two.

1st. Strict conformity at certain points to values calculated from actual data.

2d. Regularity in the graduation.

It will be observed that the logarithms of the proportions born alive and surviving ages 1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85, as calculated from actual data, are identical with those in the interpolated table. More frequent coincidence would fail, for certain intervals of age, to secure the desired regularity.

From these values we find, by inspection, that the logarithms of the reciprocals of the probabilities of surviving equal consecutive intervals of age diminish from birth, until they attain a minimum between ages 5 and 25 (near age 14), then gradually increase for subsequent intervals.

In effecting the interpolation, we sought to arrive only at results that, coinciding at the ages above specified with those derived from the actual data, should represent the logarithms of the reciprocals of the probabilities of surviving consecutive annual intervals of age as diminishing from birth to a minimum at some point between ages 5 and 25, then gradually increasing for subsequent intervals of age; and that the differences between these logarithms should also advance without manifest irregularity, increasing from, at latest, age 25 to extreme old age.

Two distinct functions of interpolation were employed.

1st. The *exponential.*

For $\lambda\, L_x$, write $\phi_x$.

$$\phi_x = \phi_a + (\phi_b - \phi_a)\,\frac{q^{x-a} - 1}{q^{b-a} - 1},$$

in which $\phi_a$, $\phi_b$, $\phi_c$ are known values of the function $\phi_x$, corresponding to ages $a$, $b$, and $c$. $q$ is to be determined. If the terms be *equidistant*, that is, if $c - b = b - a$,

$$q^{b-a} = \frac{\phi_c - \phi_b}{\phi_b - \phi_a},$$

and

$$\phi_x = \phi_a + \frac{(\phi_b - \phi_a)^2}{(\phi_c - \phi_b) - (\phi_b - \phi_a)} \cdot (q^{x-a} - 1).$$

If the terms be *not* equidistant, the determining of $q$ will involve the solution of quadratic or higher equations.

2d. The *algebraic*.

$$\phi_x = \phi_a \frac{A_x}{A_a} + \phi_b \frac{B_x}{B_b} + \phi_c \frac{C_x}{C_c} + \phi_d \frac{D_x}{D_d} \ldots\ldots + Q\,\Pi_x\,;$$

in which

$$\Pi_x = x - a \,.\, x - b \,.\, x - c \,.\, x - d \,.\, \ldots\ldots,$$

and

$$A_x = \frac{\Pi_x}{x-a},\ B_x = \frac{\Pi_x}{x-b},\ C_x = \frac{\Pi_x}{x-c},\ D_x = \frac{\Pi_x}{x-d},\ \ldots\ldots;$$

$Q$ may be zero, or an arbitrary constant real and finite, or a real function involving only integral powers of the variable, and which cannot cause the term $(Q\,\Pi_x)$ to become infinite or indeterminate for any value of the variable within the limits assigned for interpolation, or between those corresponding to the extreme given values of the function.

When $x = a$, $\frac{A_x}{A_a}$ $\left\{\begin{array}{l}\text{obviously becomes } \textit{unity}, \text{ and terms indepen-}\\ \text{dent of this factor } \textit{vanish}.\end{array}\right.$

$b$, $\frac{B_x}{B_b}$ " " "

$c$, $\frac{C_x}{C_c}$ " " "

$d$, $\frac{D_x}{D_d}$ " " "

Another convenient function for interpolation when three terms are given, but which was not employed in framing the present table, is the general *parabolic*.

$$\phi_x = \phi_a + (\phi_b - \phi_a)\left(\frac{x-a}{b-a}\right)^q,$$

in which

$$q = \frac{\lambda \dfrac{\phi_c - \phi_a}{\phi_b - \phi_a}}{\lambda \dfrac{c-a}{b-a}}.$$

The exponential involves but *three* known values of the function.

The number of known values that may enter into the interpolation by the algebraic is *unlimited;* but, without care, the resulting series will often be quite eccentric.

Given, logarithms of the proportions born alive, and surviving ages

1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85; required ($\lambda L_x$) the logarithms of the proportions surviving each intermediate anniversary of birth.

By the exponential formula values between ages

| | | |
|---|---|---|
| 25 and 38 | were respectively interpolated from known values of the function for ages . . . . . . | 25, 35, and 45. |
| 35 and 48 | | 35, 45, and 55. |
| 45 and 58 | | 45, 55, and 65. |
| 55 and 68 | | 55, 65, and 75. |

Values from 73 to age 105, inclusive, were interpolated from known values of the function for ages 65, 75, and 85.

By the above it appears that duplicate values were obtained at ages 36 and 37, 46 and 47, 56 and 57.

The results deduced from these interpolations conform strictly to the conditions imposed, except near the joining points of the several series, where appear irregularities in the first and second orders of differences. These manifest irregularities were then corrected for the several intervals, by adding to the result at each of the several ages the corresponding value of $\Delta_x$, derived from the simple algebraic function

$$\Delta_x = \Delta_g \frac{x-a \,.\, x-b \,.\, x-c \,.\, x-h}{g-a \,.\, g-b \,.\, g-c \,.\, g-h} + \Delta_h \frac{x-a \,.\, x-b \,.\, x-c \,.\, x-g}{h-a \,.\, h-b \,.\, h-c \,.\, h-g}.$$

In applying the correction to ages between 35 and 48, $a$, $b$, $c$, $g$, and $h$ equalled respectively 35, 45, 55, 36, and 37. $\Delta_{36}$ and $\Delta_{37}$ were the differences between the duplicate values for ages 36 and 37. The difference was positive when the one of the duplicate values first obtained was the greater.

In correcting between ages 45 and 58, $a$, $b$, $c$, $g$, and $h$ equal respectively 45, 55, 65, 46, and 47, and $\Delta_{46}$ and $\Delta_{47}$ were the differences respectively between the $\lambda L_{46}$ and $\lambda L_{47}$ just corrected, and the corresponding results derived by the exponential formula from values for ages 45, 55, and 65.

By a similar process the correction was made for values between ages 55 and 68.

A slight irregularity still existing in the second differences (the first differences from the logarithms of the probability of living) near

the joining of the series about age 36, another correction was made to the values between ages 37 and 45, viz.:

$$\Delta_x = \Delta_{34} \frac{x-35 \,.\, x-36 \,.\, x-37 \,.\, x-45 \,.\, x-46 \,.\, x-47}{34-35 \,.\, 34-36 \,.\, 34-37 \,.\, 34-45 \,.\, 34-46 \,.\, 34-47}.$$

The values for $\Delta_{34}$, being the difference between the first of the duplicate $\lambda\, L_{34}$ and the corrected second of the duplicates. $\Delta_x$ is additive, if the first of the duplicate values for $\lambda\, L_{34}$ is the greater.

The values between ages 67 and 73, inclusive, were computed from the known values at ages 65, 66, 67, and 73, by assuming the third order of differences constant.

$$\lambda\, L_{73} = \lambda\, L_{65} + 8\,\Delta + 28\,\Delta_2 + 56\,\Delta_3.$$

$\Delta$ and $\Delta_2$ were derived from the original value for $\lambda\, L_{65}$, and from the corrected values for $\lambda\, L_{66}$ and $\lambda\, L_{67}$. $\Delta_3$ was then readily found, and consequently the values required between ages 67 and 73. A modification of the method here indicated might have been applied with advantage to the correction of irregularities near the points of junction in other parts of the table.

From the given values of $\lambda\, L_x$ for ages 3, 5, 14, 25, 35, together with the values of $\lambda\, L_x$ for ages 26 and 27, computed as above, the unknown values between ages 5 and 26 were interpolated by the algebraic formula

$$\lambda\, L_x = \phi_x = \phi_3 \frac{A_x}{A_3} + \phi_5 \frac{B_x}{B_5} + \phi_{14} \frac{C_x}{C_{14}} + \phi_{25} \frac{D_x}{D_{25}} + \phi_{26} \frac{E_x}{E_{26}} + \phi_{27} \frac{F_x}{F_{27}} + \phi_{35} \frac{G_x}{G_{35}}.$$

The forms of the functions $A$, $B$, $C$, &c. have been previously given.

From $\lambda\, L_1$, $\lambda\, L_3$, and $\lambda\, L_5$ values were deduced by the exponential formula for $\lambda\, L_2$ (= 4.887645) and $\lambda\, L_4$ (= 4.854456).

By the same formula, from $\lambda\, L_3$, $\lambda\, L_5$, and the computed value for $\lambda\, L_7$ was deduced a duplicate value for $\lambda\, L_4$ (= 4.853532). From comparison of the duplicate values for $\lambda\, L_4$, giving to the former double weight, we obtain 4.854148.

We remark that the desired regularity in the graduation, for the greater part of the table, was attained by making identical three or more consecutive values of adjoining series.

It will be observed that the interpolated results represent mortality

diminishing from birth, until attaining a minimum about age 12, then increasing gradually to age 105, the assumed terminating age of the table. Also, that the values in the column of differences headed $-\Delta \lambda p_x$ gradually increase through the greater part of the entire table, diminishing, however, between ages 17 and 22. A curve, to which the intervals of age and corresponding intensities of mortality are co-ordinates, will be concave downwards through the space where these differences diminish, if elsewhere concave upwards. The attainment of regularity at joining points in the order of differences next higher, was deemed unimportant. For the accuracy with which much of the arithmetical computation has been performed, in the preparation of this and certain other tables following, credit is due to Mr. Howard D. Marshall, of Boston.*

Life-Tables, advancing, by regular gradations, from birth to extreme old age, and conforming strictly at convenient intervals to values derived from original data, are uncommon.

The graduation of the older tables was very imperfect. The Carlisle gives the annual rate of mortality at age 20 greater than at 23; at 31, greater than at 34; at 46 greater than at 51; at 88 greater than at 89; and at 91 the same as at 101. Mr. Milne's excellent table for Sweden and Finland, (1801–5,) though less faulty, is still irregular; so also those of De Parcieux, Kersseboom, Finlaison, and others.

The valuable and elaborate English Life-Tables prepared by Dr. Farr, and published in the Reports of the Registrar-General (England), and also the one prepared by a committee of eminent actuaries to represent a law of mortality according to the combined experience of Insurance Companies, as published by Mr. Jenkin Jones, vary the results derived from actual data, to conform to assumed laws. The graduation of the Actuaries' Table is unexceptionable; that of the tables of Dr. Farr nearly so.

The important tables presented by Mr. E. J. Farren, in his instructive treatise entitled, "Life Contingency Tables, Part I.," begin with age 21, and conform strictly at decennial points to values derived from actual data. The function of interpolation adopted by him was the Calculus of Finite Differences, so far as possible; assuming, however, the intensity of mortality to advance by a constant ratio, when, either from paucity of data or other sufficient cause, the Calculus of

* Mr. Marshall has deceased since this paper was prepared, and in press.

Finite Differences was inapplicable. The results attained are entirely regular.

Many writers on this subject have felt it desirable that some simple generic law be discovered, which, by suitable changes in the constants, will *approximate* the specific laws of human mortality indicated by known tables. Among the more philosophical conceptions is the one of Mr. Gompertz (Philosophical Transactions, 1825), that for the greater part of life man momentarily loses "equal proportions of his remaining power to oppose destruction"; and consequently, that the intensity of mortality increases with advancing age by a constant ratio. Mr. Edmonds would have "the force of mortality at all ages" "expressible by the terms of three geometric series, so connected that the last term of one series is the first of the succeeding series." Dr. Farr recognized the principle in framing his English Tables for 1841; treating "the two series of numbers representing the mortality from 15 to 55, and from 55 to 95, as geometrical progressions. The ratios were derived from a comparison of the increase in the mortality at 15 - 20, 25 - 30, 35 - 40, &c.; and the increase at 20 - 25, 30 - 35, 40 - 45, &c.; and the first terms were derived from these ratios, and the sums of the series which they formed."

Mr. Orchard's method, as described by Mr. Gray in the Assurance Magazine, (London,) for July, 1856, was the adoption of "two consecutive series, having constant second differences," to represent the proportions living from age 20 to 80 and from 80 to 96, the terminating age of his table. He wished "to find a *simple algebraical* relation which should passably well represent some of our best tables." The advantage claimed for a table so constituted "is, that it admits, by the application of simple analytical processes, of the independent formation of any of the values which ordinarily require the aid of a formidable array of the results of previous computation." The same paper gives a *single* algebraical function of the second degree proposed by Mr. Babbage, which is said to represent, nearly, the Swedish Table of Mortality.

Other methods have been proposed by mathematicians of established reputation.*

* A valuable contribution to this department of the science of Vital Statistics was read before the American Association, at its late meeting, by President McCay of South Carolina.

## B. Discussion of Certain Methods for converting Ratio of Deaths to Population, within given Intervals of Age, into Logarithms of the Probability that one living at the Earlier Age will attain the Later. With Illustrations from English and Prussian data.

In the paper immediately preceding, a method has been indicated for the conversion of mortality into probability of living from a comparison of *three* consecutive ratios, one preceding and another following the specified interval. In the present paper the results so derived will be compared with others obtained from a *single* ratio.

Let $m$ (identical with $M$ in the preceding paper) represent the rate of annual mortality for any interval of age, or the ratio $\left(\frac{D}{P}\right)$ of the number annually dying to the number living in the community within that interval of age.

If the *population* be *stationary*, $m_{a/b}$ (which equals $\frac{D_{a/b}}{P_{a/b}}$), the rate of annual mortality for the interval between ages $a$ and $b$, will equal

$$\frac{L_a - L_b}{\int_a^b L_x\,dx} = \frac{\int_a^b - d\,L_x}{\int_a^b L_x\,dx}.$$

If also the *deaths* be supposed *uniformly distributed* throughout the interval of age, i. e. $-d\,L_x$, constant, the numerator $\left(\int_a^b - d\,L_x\right)$ will represent the sum of a series of constants, and the denominator $\left(\int_a^b L_x\,dx\right)$ the sum of a series of values progressing by a common difference; hence the value of the fraction will be *independent of the extent of the interval*, and will vary only with the *mean age*.

If for $\frac{b+a}{2}$, the mean age, we substitute $z$, and assume for $k$ any arbitrary value, $m_{\overline{z-k}/\overline{z+k}}$ will be *constant for all values of the arbitrary*, provided $2k$ does not exceed $(b-a)$ the limits of age within which the uniformity of distribution was assumed.

It will follow that $\frac{L_{z-k}}{L_{z+k}}$, the value of the probability that one living at the earlier age, $z-k$, will attain the later, $z+k$, expressed in terms of the known annual rate of mortality $(m_{a/b})$, and of the arbitrary $(k)$, is

$$\frac{1 - k\,m_{a/b}}{1 + k\,m_{a/b}}.$$

Hence the probability of surviving the entire period $(b-a)$ is

$$\frac{1-\frac{b-a}{2}\,m_{a/b}}{1+\frac{b-a}{2}\,m_{a/b}};$$

and the probability of surviving the middle year of the period is

$$\frac{1-\frac{1}{2}\,m_{a/b}}{1+\frac{1}{2}\,m_{a/b}}.$$

Again, if the *population* be *stationary*, $m_{x/\overline{x+dx}}\,.\,d\,x$ (for which put $m_{d\,x}\,.\,d\,x$), the intensity of mortality at age $x$, or the rate of momentary mortality at that age, will equal

$$\frac{-d\,L_x}{L_x}=-d\underset{\epsilon}{\lambda}\,L_x=-\underset{\epsilon}{\lambda}\,\frac{L_{\overline{x+dx}}}{L_x}=-\underset{\epsilon}{\lambda}\,p_{x/x+dx},$$

(for which put $-\underset{\epsilon}{\lambda}\,p_{d\,x}$), the Napierian logarithm, with the algebraic sign changed, of the probability of surviving a moment of time from age $x$.

Hence $\int_a^b m_{d\,x}\,d\,x$, the integral within the limits of the ages $a$ and $b$ of the intensity of mortality, will equal $-\underset{\epsilon}{\lambda}\,p_{a/b}$, the Napierian logarithm, with its sign changed, of the probability that one living at the earlier age ($a$) will attain the later ($b$).

"A rate of mortality" "derived from the integration $-\frac{1}{L}\,d\,L$" has been happily styled the "integral rate of mortality."*

Assuming *deaths uniformly distributed*, $m_{d\,x}$ becomes equal to $m_{a/b}$; that is, the rate of annual mortality at the mean age equals the rate of annual mortality for the entire interval; consequently

$$-\underset{\epsilon}{\lambda}\,p_{d\,x}=m_{a/b}\,.\,d\,x;$$

that is, the Napierian logarithm, with its sign changed, of the probability of surviving a moment of time at the middle of the specified interval, equals the rate of annual mortality for the interval, multiplied by the differential of the mean age.

* Life Contingency Tables, Part I., by E. J. Farren. In the same connection is stated the important proposition, that "whatever progression prevails among the integral rates of mortality at different ages, the same progression will be found to prevail among the logarithms of the probabilities of living, and *vice versa*."

The intensity of mortality at age $z$ (when deaths are uniformly distributed) being the middle term $\left(\frac{-d\,L_z}{L_z}\right)$ of a series of reciprocals of an arithmetical progression, is less by a small proportion than the average value of the terms constituting the series; hence $(m_{a/b})$ the rate of annual mortality for the interval of age $b - a$ is somewhat *less* (in the case of such uniform distribution) than $\left(\int_a^b m_{dz} \,.\, d\,z\right)$ the integral rate of mortality for the interval, or than its equivalent $(-\lambda\, p_{a/b})$, the Napierian logarithm, with the sign changed, of the probability that one living at the earlier age ($a$) will attain the later age ($b$).

To convert the Napierian to the common logarithm, we multiply by $\mu$ $(= .4342945)$, the modulus of the common system.

## PRUSSIA. 1839, '40, '41.

### Table comparing Logarithms of Probabilities of Surviving, computed by different Methods.

| Ages $a, b$. | Ratio of Deaths to Population. | Common Logarithm, with changed Sign, of the Probability that one living at the Earlier Age in each Interval will attain the Later. | | | |
|---|---|---|---|---|---|
| | Mortality. | Integral. | Approximate. | | |
| | $m$ | $-\lambda\, p$ each from *three* consecutive Ratios. | $-\lambda \dfrac{1 - m\,\frac{b-a}{2}}{1 + m\,\frac{b-a}{2}}$ | $-(b-a)\,\lambda \dfrac{1 - \frac{m}{2}}{1 + \frac{m}{2}}$ | $-(b-a)\,\mu\,.\,m$ |
| | *A* | *B* | *C* | *D* | *E* |
| 0 - 5 | .0802238 | .157112* | .176598 | .174297 | .174204 |
| 5 - 7 | .0152056 | .013155 | .013208 | .013208 | .013208 |
| 7 - 14 | .0077790 | .023557 | .023655 | .023649 | .023649 |
| 14 - 20 | .0062978 | .016416 | .016413 | .016411 | .016411 |
| 20 - 25 | .0089397 | .019425 | .019416 | .019412 | .019412 |
| 25 - 30 | .0096939 | .021058 | .021054 | .021050 | .021050 |
| 30 - 35 | .0108317 | .023537 | .023527 | .023521 | .023521 |
| 35 - 40 | .0131780 | .028637 | .028626 | .028616 | .028616 |
| 40 - 45 | .0144675 | .031449 | .031430 | .031416 | .031416 |
| 45 - 55 | .0210345 | .092322 | .091691 | .091355 | .091352 |
| 55 - 60 | .0357042 | .077981 | .077738 | .077539 | .077531 |
| 60 - 65 | .0557995 | .122189 | .121962 | .121199 | .121167 |
| 65 - 75 | .0909134 | .415608 | .425992 | .395105 | .394832 |
| 75 - 85 | .1515098 | .722021 | .860283 | .659260 | .657999 |
| 85 and upw'ds | .2661784 | | | 1.162896 | 1.155998 |

* This value was calculated by a process described in the preceding paper, from population under age 5; from deaths for the intervals of age 0 - 1, 1 - 3, and 3 - 5; and from the rate of annual increase of births estimated from registered births for the six years 1836 - 41.

## ENGLAND AND WALES.

TABLE COMPARING LOGARITHIMS OF PROBABILITIES OF SURVIVING, COMPUTED BY DIFFERENT METHODS.

*Deaths (Seven Years)* 1838 – 44.
*Population computed to Middle of* 1841.
Ninth Rep. Reg.-Gen., pp. 176, 177.

| Ages $a, b$. | Ratio of Deaths to Population. MORTALITY. $m$ | Common Logarithm, with changed Sign, of the Probability that one living at the Earlier Age in each Interval will attain the Later. INTEGRAL. $-\lambda p$ Duplicate Values, each from *two* consecutive Ratios. | Mean of the Duplicate Values. | APPROXIMATE. $-\lambda\dfrac{1-m\frac{b-a}{2}}{1+m\frac{b-a}{2}}$ | $-(b-a)\lambda\dfrac{1-\frac{m}{2}}{1-\frac{m}{2}}$ | $-(b-a)\mu.m$ |
|---|---|---|---|---|---|---|
| | *A* | *B* | | *C* | *D* | *E* |
| 0 – 1 | .1792379 | .077265 | .073073* | .078052 | .078052 | .077842 |
| 1 – 2 | .0654971 | .028133<br>.028379 | .028256 | .028455 | .028455 | .028445 |
| 2 – 3 | .0351076 | .015206<br>.015235 | .015220 | .015249 | .015249 | .015247 |
| 3 – 4 | .0250056 | .010850<br>.010854 | .010852 | .010860 | .010860 | .010860 |
| 4 – 5 | .0184203 | .007995<br>.007998 | .007997 | .008000 | .008000 | .008000 |
| 5 – 10 | .0091272 | .019686<br>.019789 | .019738 | .019823 | .019820 | .019819 |
| 10 – 15 | .0052572 | .011397<br>.011425 | .011411 | .011417 | .011416 | .011416 |
| 15 – 25 | .0081967 | .035723<br>.035643 | .035683 | .035618 | .035598 | .035598 |
| 25 – 35 | .0098929 | .043033<br>.043045 | .043039 | .042999 | .042966 | .042964 |
| 35 – 45 | .0124582 | .054239<br>.054261 | .054250 | .054176 | .054105 | .054105 |
| 45 – 55 | .0165886 | .072341<br>.072636 | .072489 | .072209 | .072044 | .072043 |
| 55 – 65 | .0295429 | .130216<br>.130452 | .130334 | .129249 | .128313 | .128303 |
| 65 – 75 | .0622301 | .283777<br>.278012 | .280895 | .279528 | .270349 | .270262 |
| 75 – 85 | .1374474 | .718169<br>.649789 | .683979 | .731961 | .597869 | .596926 |
| 85 – 95 | .2842092 | 1.127822 | | | 1.242716 | 1.234305 |
| 95 – + | .4146003 | | | | 1.827064 | 1.800586 |

* This value was derived from the registered births for the eleven years 1839 – 49, and from the registered deaths under one year of age for the ten years 1840 – 49.

In each of the preceding Tables, column *A* gives rates of annual MORTALITY for the several specified intervals of age, or ratios of the average numbers annually dying in the community within the specified intervals to the numbers living within the same intervals, estimated with reference to the middle of the year or period in which the deaths occurred.

Column *B* with changed signs gives the common logarithms of the probabilities of surviving the specified intervals, each computed from THREE consecutive ratios in the column of mortality by a process described in the preceding paper. These values, which we designate *integral* values, may be assumed without appreciable error to represent truly the results demanded by actual data, and with them may be compared *approximate* values obtained by simpler processes.

The *approximate* values in the columns *C*, *D*, and *E* were each derived from SINGLE ratios in *A*.

The values in *C* were each obtained by first multiplying ($m$) the annual rate of mortality by $\left(\frac{b-a}{2}\right)$ half the number of years in the interval of age; then finding the logarithm, with changed sign, of the quotient of unity *less* this product divided by unity *plus* this product.

The values in *D* were each found by multiplying the number of years in the respective interval by the logarithm, with changed sign, of the quotient of unity *less* half the rate of mortality divided by unity *plus* half the rate.

The values in *E* were each found by multiplying the mortality by .4342945 ($\mu$), the modulus of the common system of logarithms, and by $(b-a)$ the number of years in the respective interval of age.

Whenever the decrements in the Life-Table resulting from the original data are constant, the corresponding result in *C* represents the logarithm, with changed sign, of the probability of surviving the *entire interval;* that in *D* represents the product of $(b-a)$ the number of years in the interval, multiplied by the logarithm, with changed sign, of the probability of surviving the *middle year* of the interval; and that in *E* the product of $\left(\frac{b-a}{d\,z}\right)$ the number of equal moments in the interval, multiplied by the logarithm, with changed sign, of the probability of surviving a moment of time at the middle of the interval. Whenever the decrements in the Life-Table are *increasing*, the above

results are each *less* than the respective logarithm; and when *decreasing*, *greater*.

The results in $E$ should in all cases be somewhat less than those in $D$, although generally the approximation is so close that values in $E$ may without appreciable error be substituted for those in $C$.

The results in $D$ are likewise less than corresponding ones in $C$.

The results in $C$ are *less* than the integral values in $B$, whenever the decrements between the proportions surviving at equidistant ages in the Life-Table, derived from actual data, form a series increasing with the age; they are *equal* to them, when the series is uniform, and *greater* than truth when the series diminishes. By reference to the Prussian Table interpolated for annual intervals, we observe that the decrements diminish from birth to age 13; increase thence to age 65; and again diminish to the age terminating the Table.

The process for deducing values in $D$ is identical with that adopted by Dr. Farr,* in briefly calculating approximate Life-Tables. After determining from values so obtained the proportions of the living at certain ages, he assumed that the proportions within the several intervals were series in arithmetical progression.† It is not unusual, in framing Life-Tables from population and mortality statistics, to let $\frac{1 - \frac{1}{2} m}{1 + \frac{1}{2} m}$ equal the probability of surviving the middle year of a given interval, then, assuming some law of relation, to determine values for intermediate ages. Results so deduced will commonly represent the probability of living for a large part of life somewhat greater than truth demands.

### C. Process for deducing accurate Average Duration of Life, Present Value of Life-Annuities, and other useful Tables involving Life-Contingencies, from Returns of Population and Deaths, without the Intervention of a General Interpolation.

The logarithms of the proportions surviving at certain ages ($\lambda\ L_x$) are obtained, by successively adding to the logarithm of a number as-

* To this distinguished writer the science of vital statistics is largely indebted for valuable, extensive, and varied contributions.

† Fifth Report Reg.-Gen. Eng., p. 362.

sumed living at birth, or other specified age, the logarithms of the probabilities of surviving subsequent intervals. Processes for accurately and for approximately determining the logarithms of the probabilities of surviving have been indicated in the previous papers.

Average future duration (or expectation) of life ($E_x$) expressed in years for any age ($x$) may be obtained by multiplying by the differential of the age ($d\,x$) the integral of the proportions surviving within the limits of the given age and of the greatest tabular age $\left(\int_x^{105} L_x\right)$, and dividing the product by the proportions living at the given age.

That is,

$$E_x = \frac{d\,x \int_x^{105} L_x}{L_x},$$

in which 105 is assumed the greatest tabular age.

A close approximation to this value may be found by dividing ($\sum_x^{105} L_x = L_x + L_{x+1} + \ldots\ldots L_{105}$) the sum of the proportions living at the given age and at each subsequent anniversary by ($L_x$) the proportions living at the given age, and from the quotient deducting the half of unity; that is,

$$E_x = \frac{\sum_x^{105} L_x}{L_x} - \tfrac{1}{2}, \text{ nearly.}$$

The latter is the more common process.

The formula expressing the value of a life-annuity, or the present value of one dollar payable at the end of each year during the remainder of the life of the annuitant after attaining a given age, is

$$\frac{L_{x+1}\,v + L_{x+2}\,v^2 + \ldots\ldots L_{105}\,v^{105-x}}{L_x};$$

in which $v$ is the present value of one dollar due one year hence at a given rate of interest.

This expression may readily be converted into the well-known symmetrical form

$$\frac{L_{x+1}\,v^{x+1} + L_{x+2}\,v^{x+2} + \ldots\ldots L_{105}\,v^{105}}{L_x\,v^x},$$

which equals

$$\frac{L_x\,v^x + L_{x+1}\,v^{x+1} + L_{x+2}\,v^{x+2} + \ldots\ldots L_{105}\,v^{105}}{L_x\,v^x} - 1,$$

$$= \frac{\sum_x^{106} L_x v^x}{L_x v^x} - 1.$$

Given ($L_0$, $L_1$, $L_3$, &c.) the proportions born, and surviving ages 1, 3, 5, 14, 25, 35, 45, 55, 65, 75, and 85, according to the law of mortality prevailing in Prussia; required corresponding average future duration of life, life-annuities, and premiums annual and single.

In order to determine values for $\int_x^{105} L_x$ and $\sum_x^{106} L_x v^x$, some law of relation must be supposed to exist between the known values of each of the functions $L_x$ and $L_x v^x$; and this law obviously should represent numbers diminishing with advancing age.

The law may either be expressed by a single formula (as, for instance, the algebraic of the eleventh order), or by a series of distinct formulæ. In consequence of the very great arithmetical labor involved in its practical application, it will not often be thought desirable to adopt a single formula.

When the known values are *equidistant*, $n$ being the number of years in each interval, let

$$S_x = L_x + L_{x+n} + L_{x+2n} + \ldots,$$

and

$$S'_x = L_x v^x + L_{x+n} v^{x+n} + L_{x+2n} v^{x+2n} + \ldots;$$

then will

$$\int_x^{105+} L_x = \int_x^{x+n} S_x,$$

and

$$\sum_x^{106} L_x v^x = \sum_x^{x+n} S'_x.$$

Formulæ which express laws of relation supposed to exist between *four* given values we style *four-point formulæ;* and so for any other number of given values.

The solution of the *four-point algebraic equation*

$$X = \alpha + \beta x + \gamma x^2 + \delta x^3,$$

in which $\alpha$, $\beta$, $\gamma$, $\delta$ are unknown, and independent of the variable ($x$), may assume several forms; one of the more convenient of which for our present purpose is

$$X = B\frac{x-c}{b-c} + C\frac{x-b}{c-b} + x-b\,.\,x-c \left\{ \begin{array}{c} \theta_A^2 \dfrac{x-d}{a-d} \\ + \theta_B^2 \dfrac{x-a}{d-a} \end{array} \right\},$$

in which

$$\theta_A^2 = \left\{ \frac{C - B}{c - b} - \frac{B - A}{b - a} \right\} \frac{1}{c - a},$$

$$\theta_B^2 = \left\{ \frac{D - C}{d - c} - \frac{C - B}{c - b} \right\} \frac{1}{d - b},$$

and $A$, $a$, $B$, $b$, $C$, $c$, $D$, $d$, are known corresponding values of the co-ordinates $X$, $x$.

Then will

$$d\,x \int_b^c X = \frac{c - b}{2} \left\{ C + B - \frac{\overline{c - b}^2}{3} \left\{ \begin{array}{l} \theta_A^2 \dfrac{d - \frac{1}{2}\,\overline{b + c}}{d - a} \\ + \theta_B^2 \dfrac{a - \frac{1}{2}\,\overline{b + c}}{a - d} \end{array} \right\} \right\}$$

$$= \frac{c - b}{2} \{ C + B + H \};$$

in which $H$ is substituted for

$$- \frac{\overline{c - b}^2}{3} \left\{ \begin{array}{l} \theta_A^2 \dfrac{d - \frac{1}{2}\,\overline{b - c}}{d - a} \\ + \theta_B^2 \dfrac{a - \frac{1}{2}\,\overline{b - c}}{a - d} \end{array} \right\}.$$

Also,

$$\frac{C - B}{2} + \Sigma_b^c X = \frac{c - b}{2} \{ C + B + \left( 1 - \frac{1}{\overline{c - b}^2} \right) H \}.$$

If the terms be equidistant, that is, if

$$d - c = c - b = b - a,$$

$H$ becomes

$$\frac{C + B - \overline{D + A}}{12}.$$

Then

$$d\,x \int_b^c X = \frac{c - b}{2} \left\{ C + B + \frac{C + B - \overline{D + A}}{12} \right\},$$

and

$$\frac{C - B}{2} + \Sigma_b^c X = \frac{c - b}{2} \left\{ C + B + \frac{C + B - \overline{D + A}}{12} \left( 1 - \frac{1}{\overline{c - b}^2} \right) \right\}.$$

The *three-point exponential* formula

$$X = \alpha + \beta \gamma^x,$$

$\alpha$, $\beta$, and $\gamma$ being unknown, and independent of the variable $x$, may take the form

$$X = A + (B - A)\frac{q^{x-a} - 1}{q^{b-a} - 1};$$

in which

$$\frac{q^{c-a} - 1}{q^{b-a} - 1} = \frac{C - A}{B - A},$$

whence may be determined the value of $q$.

$$\left.\begin{array}{r} dx\int_a^b X = \frac{1}{Q} \\ \frac{B-A}{2} + \Sigma_a^b X = \frac{1}{2}\frac{q+1}{q-1} \end{array}\right\} \overline{B-A} + \overline{b-a}\left\{A - \frac{B-A}{q^{b-a}-1}\right\}$$

$$\left.\begin{array}{r} dx\int_b^c X = \frac{1}{Q} \\ \frac{C-B}{2} + \Sigma_b^c X = \frac{1}{2}\frac{q+1}{q-1} \end{array}\right\} \overline{C-B} + \overline{c-b}\left\{A - \frac{B-A}{q^{b-a}-1}\right\}$$

$Q$ is the Napierian logarithm of $q$.

When the terms are equidistant, i. e. $c - b = b - a$,

$$q = \left(\frac{C-B}{B-A}\right)^{\frac{1}{b-a}};$$

$$\frac{1}{Q} = \frac{\overline{b-a}\,.\,\mu}{\lambda\frac{C-B}{B-A}};$$

and

$$\frac{B-A}{q^{b-a}-1} = \frac{\overline{B-A}^2}{C-B-\overline{B-A}}.$$

$\mu$ is (.4342945) the modulus of the common system of logarithms.

When the terms are not equidistant, the application of the exponential function involves the resolution of equations of higher than the first degree.

The *three-point parabolic* formula

$$X = \alpha + \beta\,(x - a)^{\gamma}$$

may become

$$X = A + (B - A)\left(\frac{x-a}{b-a}\right)^q;$$

in which

$$q + 1 = \frac{\lambda\frac{\overline{C-A}\,.\,\overline{c-a}}{\overline{B-A}\,.\,\overline{b-a}}}{\lambda\frac{c-a}{b-a}}.$$

Then will

$$d\,x \int_a^b X = \overline{b-a}\,A + \frac{\overline{b-a}\,.\,\overline{B-A}}{q+1}$$

and

$$d\,x \int_b^c X = \overline{c-b}\,A + \frac{\overline{c-a}\,.\,\overline{C-A}}{q+1} - \frac{\overline{b-a}\,.\,\overline{B-A}}{q+1}.$$

The *finite* integral of $(x-a)^q$ advances in the form of *a series*, no application of which has been made in the illustrations which follow.

Of the functions above enumerated, the algebraic will commonly prove the most simple in practice, but will not in all cases satisfy the conditions required. When assumed to express the law of relation between certain known values of the function $L_x$ or $L_x v^x$, a portion of the resulting series of numbers between the known values may increase with advancing age, rather than diminish.

The values between $B$ and $C$, derived from the algebraic formula assigning a law of relation between the *four* known values $A$, $B$, $C$, and $D$, *lie between* corresponding duplicate values derived from two algebraic formulæ, one a function of the *three* known values $A$, $B$, and $C$, and the other of the *three* values $B$, $C$, and $D$. When the relations of the known values to each other are such that the series resulting from each of the latter formulæ diminish continuously with advancing age from $A$ to $C$ and from $B$ to $D$ respectively, then that portion between $B$ and $C$ of the single algebraic series connecting the four values $A$, $B$, $C$, and $D$ must diminish continuously.

The series of values resulting from the algebraic formula assigning a law of relation between the *three* known values $A$, $B$, and $C$ will continuously diminish from $A$ to $C$ *only* when $\frac{A-B}{\overline{b-a}^2}$ and $\frac{B-C}{\overline{c-b}^2}$ are each positive and *greater* than $\frac{A-C}{\overline{c-a}^2}$; or, if the three terms be equidistant, *only* when $\left(\frac{B-A}{C-B}\right)$ the value of the ratio of the first differences is between $\frac{1}{3}$ and 3, and the differences themselves negative. Similar relations obviously obtain when the three known values are $B$, $C$, and $D$.

Applying this test to the Prussian Life-Table, we first find that the algebraic function assigning a law of relation between the *three* known values does not completely satisfy the conditions for the proportions surviving ages 0, 1, 3; 3, 5, 14; 75, 85, 95; and 85, 95, 105; that

is, for the extremes of the table, the values there rapidly diminishing; and also for ages 3, 5, and 14, where there is a great disparity in the length of the intervals of age. It will hereafter appear that eccentricities at the older ages may be disregarded in constructing tables of future duration of life, and of life-annuities, without materially affecting the correctness of the results for earlier ages.

TABLE I.

AVERAGE FUTURE DURATION OF LIFE IN PRUSSIA.

*Algebraic Integration.*

| Ages. | Proportions Born, and Living at Specified Ages in Prussia, calculated, by the Integral Method, from *three* Consecutive Ratios of Deaths to Population. | | | Sum of ($L_x$) the Proportions Living at the given Age and at all subsequent Ages specified. $L_x+L_{x+10}+L_{x+20}+\dots$ | Aggregate Number of Future Years that ($L_x$) the Proportions surviving Specified Ages will live. $\frac{10}{2}\left\{S_x+S_{x+10}+\frac{S_x+S_{x+10}-S_{x-10}-S_{x-20}}{12}\right.$ | Average Future Duration of Life. $\frac{dx\int_x^{105}L_x}{L_x}$ |
|---|---|---|---|---|---|---|
| | $L_x$ | Ages. | $L_x$ | $S_x$ | $dx\int_x^{105}L_x$ | $E_x$ |
| 5 | 69,916 | 5 | 69,916 | 364,916 | | |
| 14 | 64,249 | 15 | 63,748 | 295,000 | 2,626,778 | 41.21 |
| 25 | 59,159 | 25 | 59,159 | 231,252 | 2,012,408 | 34.02 |
| 35 | 53,386 | 35 | 53,386 | 172,093 | 1,448,721 | 27.14 |
| 45 | 46,488 | 45 | 46,488 | 118,707 | 948,047 | 20.39 |
| 55 | 37,585 | 55 | 37,585 | 72,219 | 524,773 | 13.96 |
| 65 | 23,706 | 65 | 23,706 | 34,634 | 215,941 | 9.11 |
| 75 | 9,104.2 | 75 | 9,104.2 | 10,927.6 | 54,597 | 6.00 |
| 85 | 1,726.7 | 85 | 1,726.7 | 1,823.4 | 5,847 | 3.39 |
| | | 95 | 96.1 | 96.7 | — 232 | |
| | | 105 | .64 | .64 | | |

In the preceding table the *first* of the columns headed $L_x$ gives the proportions surviving certain ages according to the law of mortality prevailing in Prussia*; the probability of surviving each of the several intervals being calculated from three consecutive ratios of deaths to populations. In the *second* of the columns headed $L_x$ the values for ages 95 and 105 were computed from the logarithms of the proportions surviving ages 65, 75, and 85, by the exponential formula which expresses the value of the required logarithms in terms of the age, and of the three given logarithms. The number surviving age 15 (63,748) was obtained by assuming an algebraic law of relation for the proportions surviving the *four* ages 5, 14, 25, and 35.

The next column $(S_x)$ gives the sum of the proportions surviving the given age and all subsequent specified ages.

The values in column headed $d\,x \int_x^{105} L_x$ give the aggregate number of future years of life that the proportions surviving given ages will enjoy, according to the prevailing law of mortality, and were each computed from four equidistant values in the preceding column $(S_x)$, by means of the formula

$$d\,x \int_x^{105} L_x = \frac{n}{2}\left\{S_x + S_{x+n} + \frac{S_x + S_{x+n} - S_{x-n} - S_{x+2n}}{12}\right\}.$$

The values thus obtained, divided by the corresponding proportions living, give the average future duration of life.

We have already called attention to the unsatisfactory nature of the values resulting from the use of the algebraic formula when the given numbers rapidly diminish, as in the Life-Table after about age 75

Table II. will compare corresponding results obtained by different formulæ and processes.

In the third column of Table II. the integrations were effected by the exponential formula when the three given values involved in the equation were equidistant; when not equidistant, the parabolic formula was adopted.

The parabolic and the exponential formulæ each afford results that constantly diminish with advancing age.

The process of integration by the algebraic formula involving four known values is the simplest, and between ages 15 to 75 is entirely satisfactory; from 5 to 15, and from 75 upwards, the values afforded are not so reliable; and from 95 to 105, duration of life is represented as *negative*.

In Table IV. we observe that the first three columns of average future duration of life present results, for the larger part of life, *almost identical.*

Values by the algebraic formula slightly exceed those of the following column, calculated by a combination of parabolic, exponential, and algebraic formulæ. The excess at specified ages from 15 to 55 inclusive is only the one-hundredth part (.01) of a year, or *about four days.*

## TABLE II.

COMPARISON OF TEMPORARY AGGREGATE FUTURE DURATION OF LIFE, CALCULATED BY DIFFERENT METHODS, FROM THE PROPORTIONS SURVIVING ACCORDING TO THE PRUSSIAN LIFE-TABLE.

| Ages. | Proportions Born alive, and Surviving certain Ages. | The Aggregate Number of Years of Life which the Proportions Surviving at the Commencement of certain Intervals of Age will enjoy during each Interval. | | | | |
|---|---|---|---|---|---|---|
| $x$ | $L_x$ | $dx\int_x^{x+n} L_x$ | | | $\frac{L_{x+n}-L_x}{2} + \Sigma_x^{x+n} L_x$ | $\frac{L_{x+n}+L_x}{2}$ |
| | | Parabolic and Exponential | | Algebraic Formula. | By Annual Interpolation. | Equidifferent Method. |
| | | Duplicates. | Mean. | | | |
| 0 | 100,389 | 87,827* | | | 91,665 | 91,665 |
| 1 | 82,941 | 155,560*<br>155,176 | | | 155,494 | 156,578 |
| 3 | 73,637 | 142,992<br>142,359* | | 142,792 | 143,251 | 143,553 |
| 5 | 69,916 | 664,403*<br>666,802 | 665,602 | 656,124 | 661,937 | 668,320 |
| 15 | 63,748 | 613,405<br>615,410 | 614,407 | 614,370 | 616,016 | 614,535 |
| 25 | 59,159 | 563,826<br>563,581 | 563,653 | 563,687 | 563,655 | 562,725 |
| 35 | 53,386 | 500,393<br>500,836 | 500,614 | 500,674 | 500,322 | 499,370 |
| 45 | 46,488 | 422,257<br>423,648 | 422,952 | 423,274 | 422,990 | 420,365 |
| 55 | 37,585 | 311,573<br>306,973 | 309,273 | 308,830 | 311,376 | 306,455 |
| 65 | 23,706 | 164,599<br>155,807 | 160,203 | 161,341 | 159,662 | 164,050 |
| 75 | 9,104 | 49,992<br>45,211 | 47,601 | 48,750 | 47,769 | 54,155 |
| 85 | 1,727 | 7,137<br>5,688 | 6,412 | 6,081 | 6,368 | 9,115 |
| 95 | 96 | 285<br>209 | 247 | — 194 | 228 | 485 |
| 105 | 1 | | | | | |
| 115 | 0 | | | | | |

A comparison of the results in the third column of Table IV. with those arrived at by a general interpolation and direct summation of the proportions surviving each anniversary of birth, exhibits a differ-

* These four values were calculated by the parabolic formula; the other values in the column by the exponential.

ence at specified ages from birth to age 85 inclusive, that in but one case (at age 65) exceeds three one-hundredth parts (.03) of one year, or about *eleven days.*

The former results are deemed in every respect as satisfactory as the latter.

We observe that results by the equidifferent method compared with approved results, from birth to age 45 inclusive, are usually about one tenth of a year in excess; and that for ages above 45 the excess is much greater.

## TABLE III.

### Future Duration of Life in Prussia.

*The Temporary Future Duration of Life for the Proportions Surviving, was computed by the Parabolic Formula from Birth to Age* 1; *Exponential, from* 1 *to* 3 *and* 3 *to* 5; *Mean of Parabolic and Exponential, from* 5 *to* 15; *Algebraic, from* 15 *to* 75; *and Mean of Exponential Duplicates, from* 75 *to* 105.

| Ages. | Temporary Future Duration of Life. | Future Duration of Life. | Average Future Duration of Life. |
|---|---|---|---|
| $x$ | $dx\int_x^{x+n} L_x$ | $dx\int_x^{105} L_x$ | $\frac{dx\int_x^{105} L_x}{L_x} = E_x$ |
| 0 | 87,827 | 3,678,033 | 36.64 |
| 1 | 155,176 | 3,590,206 | 43.29 |
| 3 | 142,992 | 3,435,030 | 46.66 |
| 5 | 665,602 | 3,292,038 | 47.09 |
| 15 | 614,370 | 2,626,436 | 41.20 |
| 25 | 563,687 | 2,012,066 | 34.01 |
| 35 | 500,674 | 1,448,379 | 27.13 |
| 45 | 423,274 | 947,705 | 20.39 |
| 55 | 308,830 | 524,431 | 13.95 |
| 65 | 161,341 | 215,601 | 9.09 |
| 75 | 47,601 | 54,260 | 5.96 |
| 85 | 6,412 | 6,659 | 3.85 |
| 95 | 247 | 247 | 2.57 |

## TABLE IV.

### Comparison of Average Future Duration of Life.

*Computed, by different Processes, from the Prussian Life-Table.*

| Ages. | By the Algebraic Formula. | Parabolic, 0 - 1; Exponential, 1 - 3 and 3 - 5; Mean of Parabolic and Exponential, 5-15; Algebraic, 15 - 75; Mean of Exponential Duplicates, 75 - 105. | By Annual Interpolation. | Assuming $L_x$ within each Interval to advance by an *Equidifferent Progression.* |
|---|---|---|---|---|
| 0 | | 36.64 | 36.66 | 36.77 |
| 1 | | 43.29 | 43.27 | 43.40 |
| 3 | | 46.66 | 46.63 | 46.76 |
| 5 | | 47.09 | 47.06 | 47.19 |
| 15 | 41.21 | 41.20 | 41.17 | 41.28 |
| 25 | 34.02 | 34.01 | 34.02 | 34.09 |
| 35 | 27.14 | 27.13 | 27.14 | 27.24 |
| 45 | 20.39 | 20 39 | 20.40 | 20.53 |
| 55 | 13.96 | 13.95 | 13.98 | 14.21 |
| 65 | 9.11 | 9.09 | 9.03 | 9.61 |
| 75 | 6.00 | 5.96 | 5.97 | 7.00 |
| 85 | 3.39 | 3.85 | 3.82 | 5.55 |
| 95 | | 2.57 | 2.37 | 5.05 |

## TABLE V.

### Value, at certain Ages, of One Dollar to be paid at the End of each Year during the Remainder of Life, according to the Prussian Life-Table, with Process for determining.

*Interest of Money, Four per Cent. Algebraic Finite Integration.*

| Ages. | $L_x\left(\frac{1}{1.04}\right)^x$ | $L'_x + L'_{x+10} + L'_{x+20} + \ldots$ | $\frac{10}{2}\left\{S'_x + S'_{x+10} + \frac{.99}{100}H\right\}$ | $\frac{\Sigma_x^{106} L'_x}{L'_x} - 1$ |
|---|---|---|---|---|
| $x$ | $L'_x$ | $S'_x$ | $-\frac{L'_x}{2} + \Sigma_x^{106} L'_x$ | Life-Annuity, 4 per Cent. |
| 5 | 57,466 | 143,287 | | |
| 15 | 35,397 | 85,821 | 666,675 | 18.33 |
| 25 | 22,192 | 50,424 | 384,260 | 16.82 |
| 35 | 13,529 | 28,232 | 208,804 | 14.93 |
| 45 | 7,959 | 14,703 | 103,448 | 12.50 |
| 55 | 4,347 | 6,744 | 43,186 | 9.44 |
| 65 | 1,852 | 2,397 | 13,115 | 6.58 |
| 75 | 481 | 545 | 2,306 | 4.29 |
| 85 | 61.6 | 63.9 | 133.6 | 1.67 |
| 95 | 2.3 | 2.3 | — 13 8 | |
| 105 | .01 | .01 | | |

$$H = S'_x + S'_{x+10} - S'_{x-10} - S'_{x-20}.$$

In Table V. we observe that the ratios of the first differences of the values $\left(L_x \left(\frac{1}{1.04}\right)^x\right)$ in the second column, for ages 65 and over, are not within the required limits, $\frac{1}{3}$ and 3, and, consequently, that the values of the annuity resulting from integration by the algebraic formulæ are to an extent unsatisfactory.

Had the integration of $S'_x$ for the older ages been effected by the exponential formula, the following would have resulted.

| Ages. | $-\frac{L'_x}{2} + \Sigma_x^{x+n} S'_x$ | | $\frac{\Sigma_x^{x+n} S'_x}{L'_x} - 1$ |
|---|---|---|---|
| | Duplicates. | Mean. | |
| 55 | 43,539.1<br>42,671.2 | 43,105 | 9.42 |
| 65 | 13,417.5<br>12,711.6 | 13,065 | 6.55 |
| 75 | 2,525.4<br>2,281.3 | 2,403 | 4.50 |
| 85 | 233.3<br>188.2 | 210.8 | 2.92 |

In Table VI. the values in the third column corresponding to intervals between ages 65 and 95 are arithmetical means of duplicate values resulting from finite integration of $L'_x$ by the exponential formula. The value opposite age 95 is a *single* value similarly obtained.

*Duplicate Values and Mean.*

| Ages. | Duplicates. | Mean. |
|---|---|---|
| 65 | 10,990.8<br>10,356.0 | 10,673 |
| 75 | 2,312.6<br>2,076.1 | 2,194 |
| 85 | 229.4<br>183.0 | 206.2 |
| | Single Value. | |
| 95 | 6.3 | 6.3 |

In the same column (the third) the value of the summation from 5 to 15 (455,694) is the arithmetical mean of a result (456,371) derived by integration from the parabolic formula involving values in the preceding column for ages 3, 5, and 15, and of another (455,017) obtained by finite integration from the exponential formula involving values for ages 5, 15, and 25.

The remaining values in that column were obtained by the finite integration of a series of distinct algebraic formulæ, each involving four given values of $L_x \left(\frac{1}{1.04}\right)^x$.

When the terms in the second column ($L'_x$) are equidistant, and the intervals *unity*, $1 - \left(\frac{1}{c-b}\right)^2$ in the expression for the finite integral of the algebraic formula becomes *zero*, and the corresponding values in column third become $\frac{L'_x + L'_{x+1}}{2}$.

In the second column ($L_2 v^2$ and $L_4 v^4$) values for ages 2 and 4 were interpolated by means of the exponential formula involving values for ages 1, 3, and 5.

The value of the life-annuity ($a_x$) at each of the specified ages was obtained by dividing the corresponding value in the fourth column by that in the second, and from the quotient deducting five tenths of unity.

We observe that annuities from age 15 to 45 inclusive, according to Table V., and for subsequent specified ages according to the modification of that table by the exponential formula, are essentially identical with values in Table VI. at corresponding ages.

Our $L'_x$ (constructed according to Barrett's method) corresponds to the $D_x$ of Mr. Griffith Davies and later writers. Our $\sum_x^{106} L'_x$ (or $\sum_x^{x+n} S'_x$) is the $N_x$ employed by Dr. Farr and Mr. Gray, and the $N_{x-1}$ of Mr. Davies, adopted by Mr. David Jones, Mr. Jenkin Jones, Professor De Morgan, and others.

Unaugmented annual and single premiums to insure \$ 100, payable at the end of the year of decease, may be computed by the formulæ commonly employed, and heading the respective columns, or be taken directly from Mr. Orchard's very useful tables of "Assurance Premiums."

## TABLE VI.

**Life-Annuity, with Tables preparatory; also Tables of Unaugmented Annual and Single Premiums to insure $100, payable at the End of the Year in which Life shall terminate.**

*Interest of Money, Four per Cent per Annum. Integration by different Formulæ.*

| Ages. | $L_x \left(\frac{1}{1.04}\right)^x$ | $\frac{L'_{x+n} - L'_x}{2} + \Sigma_x^{x+n} L'_x$ | $-\frac{L'_x}{2} + \Sigma_x^{108} L'_x$ | Life Annuities, 4 per Cent. $\frac{\Sigma_x^{108} L'_x}{L'_x} - 1$ | Premiums Unaugmented. Annual. $100\left(\frac{1}{1+a_x} - \frac{.04}{1.04}\right)$ | Single. $100\left(1 - \frac{.04}{1.04} . \overline{1+a_x}\right)$ |
|---|---|---|---|---|---|---|
| $x$ | $L'_x$ | | | $a_x$ | | |
| 0 | 100,389 | 90,070 | 1,478,812 | 14.23 | 2.72 | 41.42 |
| 1 | 79,751 | 75,565 | 1,388,743 | 16.91 | 1.74 | 31.12 |
| 2 | 71,380 | 68,422 | 1,313,178 | 17.90 | 1.45 | 27.31 |
| 3 | 65,463 | 63,236 | 1,244,746 | 18.51 | 1.28 | 24.96 |
| 4 | 61,010 | 59,238 | 1,181,520 | 18.87 | 1.19 | 23.58 |
| 5 | 57,466 | 455,694 | 1,122,282 | 19.03 | 1.15 | 22.96 |
| 15 | 35,397 | 282,414 | 666,588 | 18.33 | 1.33 | 25.65 |
| 25 | 22,192 | 175,456 | 384,174 | 16.82 | 1.77 | 31.46 |
| 35 | 13,529 | 105,356 | 208,718 | 14.93 | 2.43 | 38.73 |
| 45 | 7,959 | 60,261 | 103,362 | 12.49 | 3.57 | 48.12 |
| 55 | 4,347 | 30,021 | 43,101 | 9.42 | 5.75 | 59.92 |
| 65 | 1,852 | 10,673 | 13,080 | 6.56 | 9.38 | 70.92 |
| 75 | 481 | 2,194 | 2,407 | 4.50 | 14.34 | 78.85 |
| 85 | 61.6 | 206.2 | 212.5 | 2.95 | 21.47 | 84.81 |
| 95 | 2.3 | 6.3 | 6.3 | | | |
| 105 | .01 | | | | | |

Methods for determining from the above data the values of other single life benefits, whether uniform, increasing, or decreasing, either for the entire period of life or for limited portions, may readily be devised.

So also methods analogous to those employed in framing the preceding tables may, with advantage, be adopted in constructing tables that shall afford facilities for the ready solution of questions involving *two or more* life contingencies.

We now wish rules for determining, by brief processes, values intermediate between those already obtained.

Either of the formulæ already given may be resorted to; of which the following is the simplest.

$$X = A\frac{x-b\,.\,x-c}{a-b\,.\,a-c}$$
$$+\,B\frac{x-a\,.\,x-c}{b-a\,.\,b-c}$$
$$+\,C\frac{x-a\,.\,x-b}{c-a\,.\,c-b};$$

$A$, $a$, $B$, $b$, and $C$, $c$ being known corresponding values of the co-ordinates $X$ and $x$.

The algebraic formula involving *four* given values will commonly afford results of a nature entirely satisfactory within the usual limits of inquiry.

Given, $A$, $a$, $B$, $b$, $C$, $c$, and $D$, $d$, corresponding known values of $X$, $x$; required values intermediate between $B$ and $C$. If the given terms be equidistant, and

$$n = d - c = c - b = b - a,$$

the algebraic formula will give the following: —

TABLE VII.

SPECIAL FORMULÆ FOR INTERPOLATION, INVOLVING FOUR KNOWN EQUIDISTANT VALUES OF THE FUNCTION.

*Algebraic.*

| Ages. | $X$ |
|---|---|
| $b+\frac{1}{10}n$ | $\frac{1}{10}(9B+C)+\frac{3}{2000}(3\,.\,\overline{9B+C}-19A-11D)$ |
| $+\frac{2}{10}n$ | $\frac{1}{10}(8B+2C)+\frac{8}{1000}(8B+2C-6A-4D)$ |
| $+\frac{3}{10}n$ | $\frac{1}{10}(7B+3C)+\frac{7}{2000}(3\,.\,\overline{7B+3C}-17A-13D)$ |
| $+\frac{4}{10}n$ | $\frac{1}{10}(6B+4C)+\frac{4}{1000}(3\,.\,\overline{6B+4C}-16A-14D)$ |
| $+\frac{5}{10}n$ | $\frac{1}{2}(B+C)+\frac{1}{16}(B+C-A-D)$ |
| $+\frac{6}{10}n$ | $\frac{1}{10}(4B+6C)+\frac{4}{1000}(3\,.\,\overline{4B+6C}-14A-16D)$ |
| $+\frac{7}{10}n$ | $\frac{1}{10}(3B+7C)+\frac{7}{2000}(3\,.\,\overline{3B+7C}-13A-17D)$ |
| $+\frac{8}{10}n$ | $\frac{1}{10}(2B+8C)+\frac{8}{1000}(2B+8C-4A-6D)$ |
| $b+\frac{9}{10}n$ | $\frac{1}{10}(B+9C)+\frac{3}{2000}(3\,.\,\overline{B+9C}-11A-19D)$ |

EXAMPLE. — Given, unaugmented annual premiums, from Table VI., corresponding to ages 15, 25, 35, and 45; required the premium for age 28.

The difference between ages 25 and 28 is $\frac{3}{10}$ of ($n$) the interval of age from 25 to 35; that is 28 is $b + \frac{3}{10}\,n$.

Then

$$X_{28} = \tfrac{1}{10}\,(7\,B + 3\,C) + \tfrac{7}{2000}\,(3\,.\,\overline{7\,B + 3\,C} - 17\,A - 13\,D),$$

in which $A$, $B$, $C$, and $D$ equal respectively 1.33, 1.77, 2.43, and 3.57.

$$\begin{aligned} \tfrac{1}{10}\,(7\,B + 3\,C) &= \ \ 1.968 \\ 3\,(7\,B + 3\,C) &= 59.04 \\ 17\,A + 13\,B &= 69.02\,; \\ \therefore \quad X_{28} &= \ \ 1.93. \end{aligned}$$

Required a value corresponding to age 40, from data in the column headed $-\frac{L'_x}{2} + \sum_x^{106} L'_x$. The formula is

$$X_{40} = \tfrac{1}{2}\,(B + C) + \tfrac{1}{16}\,(B + C - A - D),$$

and the given values are for ages 25, 35, 45, and 55.

$$\begin{aligned} B + C &= 312{,}080, \\ A + D &= 427{,}275\,; \\ \therefore \quad X_{40} &= 148{,}840. \end{aligned}$$

Table VII. may take the symmetrical form of

## TABLE VIII.

SPECIAL FORMULÆ FOR INTERPOLATION, INVOLVING FOUR KNOWN EQUIDISTANT VALUES OF THE FUNCTION.

*Algebraic.*

| Ages. $x$ | $X$ | |
|---|---|---|
| $b + \frac{1}{10}n$ | $\frac{1}{10}(9\,B + \ \ C)$ | $9 \times 1\,(3\,.\,\overline{9\,B + \ \ C} - 19\,A - 11\,D)$ |
| $\frac{2}{10}n$ | $\frac{1}{10}(8\,B + 2\,C)$ | $8 \times 2\,(3\,.\,\overline{8\,B + 2\,C} - 18\,A - 12\,D)$ |
| $\frac{3}{10}n$ | $\frac{1}{10}(7\,B + 3\,C)$ | $7 \times 3\,(3\,.\,\overline{7\,B + 3\,C} - 17\,A - 13\,D)$ |
| $\frac{4}{10}n$ | $\frac{1}{10}(6\,B + 4\,C)$ | $6 \times 4\,(3\,.\,\overline{6\,B + 4\,C} - 16\,A - 14\,D)$ |
| $\frac{5}{10}n$ | $\frac{1}{10}(5\,B + 5\,C) + \frac{1}{6000}$ | $5 \times 5\,(3\,.\,\overline{5\,B + 5\,C} - 15\,A - 15\,D)$ |
| $\frac{6}{10}n$ | $\frac{1}{10}(4\,B + 6\,C)$ | $4 \times 6\,(3\,.\,\overline{4\,B + 6\,C} - 14\,A - 16\,D)$ |
| $\frac{7}{10}n$ | $\frac{1}{10}(3\,B + 7\,C)$ | $3 \times 7\,(3\,.\,\overline{3\,B + 7\,C} - 13\,A - 17\,D)$ |
| $\frac{8}{10}n$ | $\frac{1}{10}(2\,B + 8\,C)$ | $2 \times 8\,(3\,.\,\overline{2\,B + 8\,C} - 12\,A - 18\,D)$ |
| $b + \frac{9}{10}n$ | $\frac{1}{10}(\ \ B + 9\,C)$ | $1 \times 9\,(3\,.\ \ \overline{B + 9\,C} - 11\,A - 19\,D)$ |

And generally, when the four terms $A, B, C$, and $D$ are equidistant,

$$X = \frac{1}{c-b}(\overline{c-x}\,B + \overline{x-b}\,C) + \frac{1}{6\,(c-b)^3} \times$$

$$\{\overline{c-x}\,.\,\overline{x-b}\,[3\,.\,(\overline{c-x}\,B + \overline{x-b}\,C) - \overline{d-x}\,A - \overline{x-a}\,D]\}.$$

The writer is not aware that any previous attempt has been made to pass by direct and *summary processes* from the immediate results of actual observations to solutions of monetary and other practical questions involving life contingencies, as *accurate* and *reliable* as those obtained by the intervention of a formidable interpolation. In view of the large and rapidly accumulating mass of population and mortality statistics, such processes seem to be demanded.

The *approximate* methods heretofore published have already been adverted to; allusion has also been made to certain formulæ adopted in the construction of *theoretical* Life-Tables, which afford facilities for the independent formation of required monetary and other values.

NOTE.—The average future duration of life for ages 15, 25, 35, 45, and 55, deduced from values in column $C$, on page 82, are from .1 to .2 of a year *less*, and those derived from values in column $E$ are from .2 to .3 of a year *greater*, than corresponding durations obtained by more accurate methods. Arithmetical means of these results exceed the true values by about .05 of a year. By giving greater comparative weight to values deduced from $C$, closer approximations will ensue.

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## II. ASTRONOMY.

### 1. A SIMPLE METHOD OF CORRECTING THE COMMON NAUTICAL METHOD OF "DOUBLE ALTITUDES" OF THE SUN, MOON, OR A PLANET, FOR THE CHANGE OF DECLINATION BETWEEN THE OBSERVATIONS. By PROFESSOR W. CHAUVENET, of the U. S. Naval Academy.

NAVIGATORS who employ, for determining their latitude, two altitudes of the sun, moon, or planet, usually assume the declination as invariable, and equal to the declination at the middle instant between

the two observations; and are content with the result thus obtained. When greater accuracy is desired, either the complete rigorous process of spherical trigonometry must be employed, or a correction must be applied to the abridged process. The latter course is followed by Bowditch in what he gives as his *Third Method of Double Altitudes*. This method consists in applying a correction to one of the altitudes, and employing the declination belonging to the other altitude as the constant declination; and to find the correction, he gives a table with three arguments, which is very embarrassing to the practical seaman. The method I propose supposes the computation carried through by the common process, employing the mean declination; and to the resulting latitude thus found, a small correction is applied, to compute which only two logarithms are required to be taken from the tables in addition to those previously employed. In order to show clearly how this correction is to be obtained, it will be necessary to recapitulate the formulæ which are the analytical expression of the well-known method given by Bowditch as his First Method. Putting

$h$ = first altitude,
$h'$ = second altitude,
$\delta$ = mean declination,
$\lambda$ = difference of the hour-angles of the body at the two observations,
$\phi$ = approximate latitude,

these formulæ are,

$$\sin A = \cos \delta \sin \tfrac{1}{2} \lambda;$$
$$\sin B = \sin \delta \sec A;$$
$$\sin C = \frac{\cos \frac{1}{2}(h + h') \sin \frac{1}{2}(h - h')}{\sin A};$$
$$\cos Z = \frac{\sin \frac{1}{2}(h + h') \cos \frac{1}{2}(h - h')}{\cos A \cos C};$$
$$\sin \phi = \cos C \sin (B + Z).$$

Now to correct the value of $\phi$ thus obtained, let

$$\phi' = \text{true latitude} = \phi + \Delta\phi;$$

then I find,

$$\Delta\phi = -\frac{\frac{1}{2}\Delta\delta \sin C}{\cos\phi \sin\frac{1}{2}\lambda},$$

in which $\Delta\delta$ represents the change of declination between the two observations. In the computation of $\phi$ we have already the logarithms

of sin $C$ and sin $\frac{1}{2}\lambda$, so that we have only to take from the tables the logarithms of $\frac{1}{2}\Delta\delta$ and cos $\phi$. It may be necessary to observe to the practical computer, that attention must be paid to the sign of sin $C$, which will be negative when the second altitude is the greater; and also that $\Delta\delta$ here expresses the increase of declination, towards the north, from the first to the second observation, so that the sign of the correction must be changed when the body is moving towards the south. All the cases of sign are covered by the following simple rule: —

*When the second altitude is the greater, apply the correction to the approximate latitude as a* NORTHING *or a* SOUTHING, *according as the body is moving towards the* NORTH *or the* SOUTH. *When the first altitude is the greater, apply the correction as a* SOUTHING *or a* NORTHING, *according as the body is moving towards the* NORTH *or the* SOUTH.

It is proper to observe, that this mode of correcting may with sufficient accuracy for nautical purposes be extended to cases where the difference of declinations is two or three degrees, and therefore occasionally to the case where two different bodies are observed, provided their declinations do not differ by more than that quantity.

Finally, when the sun is the body observed, our formula gives the correction in all cases within 1″, and therefore with all the precision required in the most precise determinations on shore with the sextant and artificial horizon.

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## 2. On a Method of Determining the Latitude of a Place from the observed Times when two known Stars arrive at the same Altitude. By Professor W. Chauvenet, of the U. S. Naval Academy.

The true sidereal times when two stars arrive at the same altitude, and the right ascensions and declinations of the stars, are data sufficient to determine the latitude of the place of observation, the altitude itself remaining wholly unknown.

Gauss's method of finding both the latitude and the clock correction from the observed clock times when *three* stars arrive at the same altitude is well known, but I cannot find that any one has examined the

case where two stars are thus observed, and the clock correction is at least approximately known, though it has very probably occurred to others. Any method, however, which will enable the observer with a sextant to be independent of the errors of his instrument, deserves to be considered. In determining the latitude by meridian observations with the sextant, it is usual to select stars which culminate at nearly the same zenith-distance north and south. The mean of the latitudes found from a pair of stars so selected will be nearly free from errors arising from the eccentricity of the sextant and the imperfect adjustment of the glasses, and from the imperfection of our refraction tables, but will still be liable to the accidental errors of division of the limb. If we confine the observations to the meridian, we can never be *entirely* free from these sources of error, except when the zenith-distances of the two stars are absolutely equal, a condition which can never be satisfied in practice. Since we are limited in sextant observations to the use of bright stars, it often happens that no suitable pair of stars can be found whose meridian zenith-distances differ by less than ten or fifteen degrees, in which case only an imperfect compensation of errors must result. But by observing one or both of the stars off the meridian, we can take them at exactly the same altitude, and thus eliminate all the errors just alluded to. At the same time, however, we introduce another source of error in their stead, namely, imperfect knowledge of the time. A discussion of the formulas (which are very simple) required in the reduction of these observations will serve to show that this new source of error is much less to be feared than the others, and therefore we can claim for the method a decided advantage so far as relates to the elimination of instrumental errors and errors of refraction. Let

$\sigma, \sigma'$ = true sidereal times of observation,
$\alpha, \alpha'$ = right ascensions of the two stars,
$\delta, \delta'$ = declinations of the two stars,
$t, t'$ = hour-angles of the two stars,
$h$ = altitude of either star,
$\phi$ = latitude of the observer;

then, the hour-angles being found by the equations

$$t = \sigma - \alpha, \qquad t' = \sigma' - \alpha',$$

we have for the two stars

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t,$$
$$\sin h = \sin \phi \sin \delta' + \cos \phi \cos \delta' \cos t'.$$

Subtracting the first of these equations from the second, we find

$$\tan \phi (\sin \delta' - \sin \delta) = \cos \delta \cos t - \cos \delta' \cos t' =$$
$$\tfrac{1}{2} (\cos \delta - \cos \delta') (\cos t + \cos t') + \tfrac{1}{2} (\cos \delta + \cos \delta') (\cos t - \cos t');$$

and resolving the sums and differences into products by the usual formulæ of trigonometry, we readily deduce

$$\tan \phi = \tan \tfrac{1}{2} (\delta' + \delta) \cos \tfrac{1}{2} (t' + t) \cos \tfrac{1}{2} (t' - t)$$
$$+ \cot \tfrac{1}{2} (\delta' - \delta) \sin \tfrac{1}{2} (t' + t) \sin \tfrac{1}{2} (t' - t).$$

To facilitate the computation of this formula, let the auxiliaries $A$ and $B$ be found by the conditions,

$$\left.\begin{aligned} A \sin B &= \sin \tfrac{1}{2} (t' - t) \cot \tfrac{1}{2} (\delta' - \delta); \\ A \cos B &= \cos \tfrac{1}{2} (t' - t) \tan \tfrac{1}{2} (\delta' + \delta); \end{aligned}\right\} \quad (1.)$$

then we have,

$$\tan \phi = A \cos [\tfrac{1}{2} (t' + t) - B]. \qquad (2.)$$

These simple formulæ occur also in the method of finding both time and latitude from three stars according to the method of Gauss above mentioned. But if one of the stars is on the meridian, (and this case would naturally be preferred,) we can resort to a still more simple method of reduction. For if we have $t' = 0$, our fundamental equations, under the form,

$$\sin h = \cos (\phi - \delta) - 2 \cos \phi \cos \delta \sin^2 \tfrac{1}{2} t,$$
$$\sin h = \cos (\phi - \delta'),$$

give

$$\sin [\tfrac{1}{2} (\delta + \delta') - \phi] = \frac{\cos \phi \cos \delta \sin^2 \frac{1}{2} t}{\sin \frac{1}{2} (\delta' - \delta)};$$

or, for practical use,

$$\sin \gamma = \frac{\cos \phi \cos \delta \sin^2 \frac{1}{2} t}{\sin \frac{1}{2} (\delta' - \delta)}, \qquad \phi = \tfrac{1}{2} (\delta' + \delta) - \gamma,$$

to compute which an approximate value of the latitude must be known.

To discuss the effect of errors in the time, let $\Delta T$ denote the (sidereal) clock correction, which may be assumed to be the same at both observations, the *rate* being duly allowed for. If then $T$ and $T'$ are the clock times of the observations, the errors in the hour-angles will be

$$d t = d T + d \,.\, \Delta T,$$
$$d t' = d T' + d \,.\, \Delta T',$$

where $dT$ and $dT'$ are the errors of observation, and $d\,.\,\Delta T$ the error in the clock correction. We shall have, by differentiating our fundamental equations,

$$dh = -\cos A\, d\phi - \cos\phi \sin A\,(15\, dT) - \cos\phi \sin A\,(15\, d\,.\,\Delta T),$$
$$dh' = -\cos A'\, d\phi - \cos\phi \sin A'\,(15\, dT') - \cos\phi \sin A'\,(15\, d\,.\,\Delta T),$$

in which $A$ and $A'$ are the azimuths of the stars reckoned from the south point. In these equations we may put $d\,h = d\,h'$, differences of altitude having been already eliminated, and we shall find, by taking the difference of the two equations,

$$\frac{d\,\phi}{15 \cos\phi} = -\frac{\sin A}{\cos A - \cos A'}\, dT + \frac{\sin A'}{\cos A - \cos A'}\, dT'$$
$$+ \frac{\sin A' - \sin A}{\cos A - \cos A'}\, d\,.\,\Delta T.$$

The coefficient of $d\,.\,\Delta T$ is equal to $\cot \frac{1}{2}\,(A' + A)$, which becomes zero when $\frac{1}{2}\,(A' + A) = 90°$, that is, when the observations are equally distant from the prime-vertical. The coefficient of $dT$ is equal to

$$\frac{\sin A}{2 \sin \frac{1}{2}\,(A' + A) \sin \frac{1}{2}\,(A' - A)};$$

which becomes zero when the stars are both observed on the meridian with a difference of azimuth of 180°. Hence, errors of observation and in the clock correction are the smaller, the nearer the stars are to the meridian, one north and the other south of the zenith.

The coefficient $\cot \frac{1}{2}\,(A' + A)$ will have the same numerical value, but with opposite signs, if the same stars are observed on both sides of the meridian. The mean of two results obtained from the same pair of stars observed on each side of the meridian, will therefore be entirely free from the effect of a small error in the clock correction. This is an important remark in relation to a method proposed to be carried out with the sextant alone.

For the star very near or on the meridian, an error in the observed time will generally produce but an inappreciable effect. But for the star off the meridian, if we put $A' = 180°$, we have

$$\tfrac{1}{15}\, d\phi = -\frac{\cos\phi \sin A}{1 + \cos A}\, d\,T = -\cos\phi \tan \tfrac{1}{2} A\, d\,T.$$

If we suppose an error of $1^{s}$ in the observed time, and that the stars are selected so that the azimuth of the star off the meridian is not more than 15°, this formula gives

$$d\phi = -1''.96 \cos\phi.$$

We see, then, that the errors to which this method is liable, when it is judiciously applied, are far within the unavoidable errors resulting from the small optical power of the sextant telescope. It is, however, an objection to it, that, in order to multiply observations on the same stars, much time must be consumed both in the observations and in the computations. I offer it chiefly as completing in some degree the methods available with the sextant, and as being (so far as I am aware) the only method which is wholly free from the errors of that instrument. It may occasionally enable an observer, possessed of only a very poor sextant and a tolerably good watch, to obtain, nevertheless, very accurate results.

The method may be applied also with the zenith telescope, the instrument by which the very accurate determinations of latitude have been made on the Coast Survey. In this case we could not observe the two stars at absolutely the same altitude, but would have to take into account the slight difference of altitude shown by the level readings in the two positions of the instrument. This is easily done, and with great accuracy. By observing the same stars at different places, differences of latitude are found almost wholly free from the errors of the catalogue places of the stars; with the advantage over the method of observing with the zenith telescope only in the meridian, that greater differences of latitude may be measured, and without the use of the micrometer; or, if the micrometer is used, by confining the observations to the vicinity of the middle of the field. This will be obvious to any one acquainted with that instrument. But whether this advantage would compensate for the sacrifice of time and trouble which the method demands, is doubted by the experienced observers of the Coast Survey, to whom the suggestion has already been made, through the able head of that work. I do not think it necessary, therefore, to develop here the modifications which the method would require in such applications; especially as they are mostly of such a nature as to occur to any observer experienced in the use of the zenith telescope. I will only remark, that the method I propose may be applied with an alt-azimuth, theodolite, or universal instrument, or any instrument which is provided with a level arranged in such a manner that it may be clamped at any angle with the axis of the telescope, and which permits a rotation of the telescope and level, thus clamped, around a vertical axis.

## 3. On a New Method of Measuring Celestial Arcs. By Alvan Clark, of Cambridgeport.

Not a year has yet elapsed since it occurred to me, that an independent movable eye-piece, of high magnifying power, for each image, might be applied with advantage in micrometrical measurements of celestial objects. On giving the subject a careful inspection, I wondered if a plan so natural and simple, and which promised so excellently to my own mind, could have escaped the attention of others. On due inquiry, I found it was really so. With the assistance of my two sons, an instrument of six inches' aperture, with a focal distance of 103 inches, has been already made and mounted. It has a pendulum clock, containing Bond's spring-governor, acting on a sector clamping to the polar axis, which gives an exceedingly equable motion to the telescope, for the space of two hours.

I have thus far used a prism with the eye-pieces, while observing, as affording a more comfortable position. Instead of the spider-line micrometer, I made a cheap dividing-machine, for graduating strips of glass, with a finely pointed diamond. The screw of the machine has sixteen threads to an inch, and an appropriate circle to determine the fractions of a revolution. Kept by the ruling-machine is a constant stock of blank pieces of common plate-glass, about four inches long and three quarters of an inch in width. There are clamps for holding such a strip on the stage or carriage of the ruling-machine, and corresponding springs for securing them under the eye-pieces of the telescope at the proper focal distance. In procuring an observation, the first step is to bring the two images to the centre of their respective fields, with the driving clock at work; then, with common dividers, take the distance between the eye-pieces, which are adjustable in distance to fit the different cases, and with a rule, or by going directly to the machine, find the included number of threads upon the screw; place a blank glass under the diamond, cut first a longitudinal line through the centre, then two cross lines, giving the number of turns to the screw which my measure with the dividers indicated to be necessary between them. This glass is then directly transferred from the machine to its place under the eye-pieces of the telescope, and the lines compared with the stars, by moving the eye

from one eye-piece to the other a number of times. If the space be found too wide or too narrow, another glass is ruled in about two minutes of time, with an estimated allowance for the errors of the first in the reading of the circle upon the screw. In about three or four trials a very close approximation is obtained. Here two persons can be employed with advantage, in turning to account a good hour for work; one constantly at the telescope and the other at the ruling-machine. In getting a series of measures in distance, the former has no reading of circles, or scales, to abstract his attention or occupy his time. His only duty is to take the glasses, one after another, as furnished, compare the distances of the lines with that of the stars, and report them to his co-worker at the machine, who, in turn, must number and keep a record of every glass he rules. He should also record the report on each ruling, at the time it is given. In this way great expedition is secured, and by keeping the one at the telescope uninformed as to the value of all the rulings until the series is completed, obliging him to pronounce on lines slightly, but purposely, misplaced, without a possible bias of judgment, the other, knowing by his record the different values furnished, is able to form a very correct estimate of the accuracy they are obtaining. A great number of observations, taken in this way, have convinced me, that, in tolerable states of atmosphere, it would be impossible for the one at the machine to mislead the assistant at the telescope two tenths of a second, right or left, from a given line. Attempts at such deceptions I have made, series after series, which have been regularly detected, and pointed out, when the weather has afforded any middling opportunity for such work, even with this small instrument. In these cases, none of the objects have been less than thirteen minutes, and in one instance over fifty-five minutes distant.

In measuring angles of position, I proceed as with a spider line, only employing in its stead a diamond line upon glass. I am looking up objects where the two are as nearly equidistant from the ecliptic as possible, and preserve my rulings for future use. For annual parallaxes, this method affords peculiar conveniences, especially where the situations of the objects demand measures of distance rather than angles of position. No question relating to extent of field has any bearing on the magnifying powers an observer may wish to employ, and, if he chooses, he may use a high power upon one object and a

low one upon the other, at the same time. No advantage could possibly be claimed for the two eye-pieces, where objects are so near each other that they come well into the field, of a suitably high power, with one. Carefully conducted and many times repeated experiments have been made for testing the accuracy of measures taken on distant objects with the two, as compared with those taken on the most favorably situated objects with one, the details of which would here be needless. But I will state, I can find no sensible advantage in the one over the other; and if I were seeking a close agreement, in a great number of trials, I should certainly resort to the two eye-pieces, for all distances between three and one hundred minutes. A distortion of the image, more or less, attends the different distances from the optical axis of the telescope which the spaces to be measured may require, though it is nothing seriously objectionable, in intervals of less than one degree. But by making the object-glass on the plan of a camera-obscura used in producing daguerreotype pictures, a mastery of five degrees or more could be secured. A good driving-clock is an important appendage to an equatorial telescope, in using the ordinary filar micrometer; and it will be evident a double necessity for it exists in this case. I would, therefore, again refer to the spring-governor, admitting that no small share of the promise attending this primitive effort is due to Mr. Bond's improvement, and his kind permission to use it in my clock. When first explained, a favorable opinion on his part was expressed upon the proposed plan of observing, which encouraged me to assume the responsibility of putting it to the test, by direct experiment. Thus have I incurred toward my excellent friend a double obligation, in connection with the double eye-piece.

The observations I have to offer, I must admit, are selected, and were made with great care, in choice states of weather; the first on the evening of August 7th, 1856, on α Ophiuchi and a star of the eighth magnitude *preceding;* the other on α Aquilæ and a fifth magnitude *following*, upon the evening of August 10th, 1856. In the first of these cases, eight observations all agree to within less than three tenths of a second, and in the other, five observations agree to within less than two tenths of a second; yet the distances are such that they could not be brought into the field of a suitably high power, with common micrometers, to be measured at all. The observations were

commenced before the stars reached the meridian, and closed when about one hour past, in both cases, so that refraction would make but little show in the work. What might be expected of the instrument, adequate in dimensions, and fitted up with a proper outlay, those professionally engaged in such matters should be able to judge. My optical experiments and labors for the past twelve years have been preying upon my pecuniary resources, so that now they are entirely insufficient for so great an undertaking, whatever might be my ambition for contributing to science, or serving my country. Much time and careful toil have been bestowed on grinding and figuring lenses, and applying them to the search of the heavens; and though the pride of my heart finds its aliment in pointing to a number of exquisitely fine new telescopic objects, you can well understand they have not "put money in my purse." But not the discouraging points attending some of my past humble enterprises, nor approaching age and infirmity, nor absence of needed aid in giving the most potent form to this novel method of making astronomical observations, can cause me to dismiss it, as Dr. Johnson did his Dictionary, "with frigid tranquillity." But I am now planning upon methods which shall be convenient and effective for using with it the spider's web. And if I judge rightly, for a certain class of measures, it will, in due time, be regarded as "a more excellent way."

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## 4. The Stability of Satellites revolving in Small Orbits. By Daniel Vaughan, of Cincinnati.

The modification which centrifugal force produces on the form of the planets and the gravity at their surfaces has long been a subject of mathematical inquiry; but on the secondary planets a much greater effect arises from the unequal attraction of the central body on their parts. The theory of the tides will enable us to calculate the result of this peculiar action. If the earth could exchange orbits with Jupiter's nearest satellite, without altering its time of rotation, our tidal force would become nearly twenty thousand times as great as it is at present, and a succession of deluges would devastate all our lands. As the

feeble gravity of the satellite is less capable of restraining the disturbance, the commotions would be more dreadful on its surface, unless (as astronomers suppose) the rotation keeps pace with the orbital revolution, so that the same side is always directed to Jupiter. This arrangement, together with the small eccentricity of its orbit, must render the satellite free from destructive tides, whatever relation may subsist between its lands and seas.

The centrifugal force arising from a rotation once in forty-two hours and twenty-seven and a half minutes would diminish the equatorial gravity of the satellite, by its $\frac{1}{181}$ part; and Jupiter's attraction would produce double this diminution on the parts of the surface in conjunction and in opposition with him. The latter force increases polar gravity about one half per cent, and accordingly there will be a difference of more than two per cent between the weight of the same body at the poles and at the points turned to the primary. The deviation from a sphere which is unavoidable would make the difference much greater.

If the same satellite were only one fourth of its present distance from Jupiter, its gravity would be entirely suspended at the parts of its surface in conjunction and in opposition with the latter body; and the planetary structure, which requires the action of gravity in every direction, could no longer be preserved. Even at the distance of ninety thousand miles from the primary, gravity would be so far reduced in these localities as to render the satellite unstable, and to lead to its dismemberment. While, therefore, the laws of motion do not preclude the possibility of planets having matter revolving around them at small distances beyond the confines of their atmospheres, the conditions of equilibrium will render it impossible for this matter to exist in a single undivided mass, either of a spherical or ellipsoidal form.

The rings of Saturn furnish an instance of matter revolving around a centre in a region so dangerous to satellites. While many astronomers have been alarmed for the safety of this planetary girdle, they have overlooked the perils to which a satellite would be exposed if it moved in so small an orbit. At the mean distance of the outer ring, a satellite as dense as Saturn would be incapable of retaining its planetary form; nor could one of double the density revolve in security in the space which the centre of the inner ring occupies. If a resisting

medium should impede celestial movements, each satellite would finally reach the surface of its primary; but, before arriving there, would undergo a dismemberment, and its fragments be permitted to move in independent orbits. It may be shown, however, that these fragments would ultimately have their orbits changed to circles; and that they would acquire and retain an annular form in their revolutions around the central body.

The existence of planetary rings seems therefore to depend on their density and their proximity to the central body, whose attraction renders it impossible that satellites could be formed or preserved in their immediate vicinity. There is also much reason to believe that the rings of Saturn are the remains of two former satellites. The fact that the inner edge of the nearer ring has been constantly approaching the planet since the time of Huyghens, proves that this appendage cannot have existed for a long time in its present condition; and if, as astronomers calculate, it will be united to the planet before a century, the fact of its recent origin will scarcely admit of a doubt. We may assert, however, with more confidence, that the matter composing the rings can never form one or two satellites.

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### 5. On the Meridian Instruments of the Dudley Observatory. By Dr. B. A. Gould, of Cambridge.

Mr. Gould described the meridian-circle and transit-instrument, now nearly completed for the Dudley Observatory, and gave some account of the principles adopted in their construction.

The meridian instruments now in use in the several observatories of the world may be classified in two divisions, — which may be designated as the German and the English styles, — and perhaps be justly described, the one as the instrument of the engineer, the other as that of the artist. For the former the circles are large and massive, frequently having a diameter equal to the entire focal length of the attached telescope; in the latter they are smaller and slighter. The new transit-circle of Professor Airy, at Greenwich, typifies the English style, and this instrument, with its counterpart at the Cape of

Good Hope, presents the merits in the most conspicuous and impressive form. It is of iron, cast in a single piece; incapable of reversal, for which the observation of collimators is substituted; without a striding or hanging level, this apparatus being superseded by observations of the meridian thread as reflected from the surface of mercury; the circle is eight feet in diameter, and read by diverging microscopes firmly imbedded in a massive pier; and the pivot-forms are investigated by means of a collimating apparatus, of which the axis of rotation itself forms a part.

The instruments of the German school are of an entirely different order,— lighter and more mobile. Their circles are small in comparison with the length of the tube; the microscopes are supported upon a frame concentric with the axis, and form one system, the position of which is known by means of an attached level, whose indications furnish a correction to be applied to the mean of their several readings. The level is used, indeed, whenever its use is possible, and a great part of the precision of the results of observation is dependent upon the delicacy with which this highly trusted instrument may be constructed and used. Frequent reversals of the instrument are deemed indispensable; and in general the structure is devised with a view to easy, rapid and frequent changes in the relative position of all those parts which may be rendered movable. To sum up,— the one class of instruments is designed for securing absolute uniformity of circumstances in all observations; the other, for attaining as great diversity of circumstance as is consistent with the retention of the same degree of accuracy.

The meridian-circle for the Dudley Observatory has been ordered of Messrs. Pistor and Martins, of Berlin, and in its form and the fundamental principles adopted my aim has been to avoid the prejudices of education and the prepossessions of taste, and if possible to exercise an eclectic judgement, using however the greatest care to shun such a composite form as would impair the unity of idea, and fail of the preponderant merit which both the English and the German forms may claim, in being consistent developments of their fundamental idea.

All this seemed not impossible, nor indeed did it seem beyond attainment to combine with such an eclectic form sundry new, and by no means unimportant, additions. This has been the endeavor, and it

remains to be seen how sound may have been the foundation for these hopes and expectations.

The object-glass is from material furnished by Messrs. Chance Brothers, of Birmingham, and made under the supervision of Mr. Masselin. It was my earnest desire that it might be ground and worked into form by some one of our own accomplished artists, but the Berlin mechanicians were unwilling to entertain any proposition of the kind, — desiring to take the whole responsibility, if any, — and were so strenuous that I refrained from pressing the matter. The clear aperture is ninety French lines; the focal length, ten English feet.

Both circles are divided, and capable of rotation round the axis, and they are read by means of four microscopes firmly set in each pier, — horizontal, not converging, although the divided silver limb is slightly oblique to prevent the dazzling image of the lamp from blinding the observer's eye. The piers being two feet in thickness, and the microscopes read from the outer side, these microscopes are not far from twenty-five inches in length, — a circumstance which gives rise to various not unimportant disadvantages; but the ingenuity and skill of Mr. Martins have surmounted the chief of these, the large amount of expansion and contraction of the metal due to changes of temperature, with great success, by leaving the metal tubes free to extend or recede without hindrance, and without affecting either the distance of the lenses or their fixity in the stone.

To obviate the chief disadvantages of attaching the microscopes to the piers, namely, those arising from the unequal changes in the piers themselves, these will be coated with oil, or some other preparation for excluding moisture, wound around with list or baize, and then encased in wood. With these precautions, I am very confident that we are justified in awaiting from this more massive construction greater advantages than would be derived from the metallic connection of the microscopes, although continually subjected to scrutiny by means of the attached ether-level.

The circles are three feet in diameter, and entirely protected on the outer side by the piers. They are of the form which long experience has recommended to Messrs. Pistor and Martins as the best, — not too heavy at the rim, and with radial arms thickening in both dimensions towards the centre. The screen-tubes for the microscopes draw back automatically as soon as the counterpoises are relieved of a portion of

their burden, and it is thus possible to have them very close to the circles, when in use, without incurring any danger of injuring the graduation when the instrument is lifted for reversal.

The eye-piece has a vertical as well as a horizontal motion; and the diaphragm, which is of course adapted for chronographic observation, is provided with both a horizontal and a vertical micrometer, — the former being especially intended for the observation of polar stars, according to the method recently adopted in the Paris Observatory, and which Professor Bache had investigated in 1849.

The method of Hansen for measuring and eliminating the effect of flexure comes from an authority too high, and commends itself too strongly, to justify us in lightly setting it aside. But advantages entirely incompatible with its employment presented themselves in such number as to induce me to accede to the earnest recommendation of the artist, and abandon the original plan of interchangeable eye-piece and object-glass. Some of the decisive arguments, briefly expressed, are the following. It is only when the most absolute symmetry has been attained in every part of the tube and its accessory parts, that the flexure is absolutely determined in this manner; otherwise, we obtain the measure of an ideal, not a real, flexure. Furthermore, not only is the formula which attributes the maximum flexure to the horizontal position, and makes the flexure in other positions a simple function of the altitude, not trustworthy, but I will not hesitate to go farther, and, paradoxical as it may appear, to express my decided conviction that the flexure is not necessarily a maximum for the horizon or minimum for the nadir and zenith, and that in almost every existing instrument, if not all, the flexure is unequal for the same altitude upon different sides of the vertical. The interchange of object-glass and eye-pieces presupposes either the absence of unsymmetrical parts within the tube, such as the apparatus for illumination and the shafts by which we regulate the amount of light admitted, or the disconnection of these from their gearing or screw-heads. Indeed, nothing like the former can be reasonably demanded, — a sacrifice which seems disproportionate to the end to be attained. Moreover, the new meridian-circle is equipped with more than a usual amount of internal mechanism, although the arrangement and support of this latter has been planned with an especial view to avoidance of any prejudicial effect arising from unsymmetric distribution of weight. The measurement

of flexure may take place without disturbing the adjustments or parts of the instrument, by some apparatus analogous to the neat and practical contrivance of Professor Challis, who arranges a pair of collimators in such a manner that they are used in connection with each other at any desired angle of altitude. Moreover, the reversal of the instrument admits of a scrutiny and check upon the determinations, which provides all needful safeguard against erroneous results.

The circles are divided to 2′, and read by microscope to 0″.1. The unit's place of the degree is always visible within the field of the microscope, and the decades of degrees are engraved upon the rim of the circle. The finders read to 10′, and by vernier to 1′.

The axis is turned within as well as without, a precaution upon which I also insisted with regard to the tube. The cube measures thirteen inches and a half on each side, and the pivots are two inches in diameter. The difficulty of obtaining a satisfactory and suitably homogeneous piece of iron for the axis may be estimated from the circumstance that even in Berlin, justly renowned as is that city for knowledge and skill in everything pertaining to the founding of iron, three successive castings had to be rejected before a satisfactory piece could be obtained; and even then it became necessary to deviate from the original plan, — not, however, as I trust, to the disadvantage of the instrument. The weight of the axis is about 350 pounds.

The illumination is entirely by gas, the light designed for the illumination of the field entering by one pivot, and that for the threads by the other. Arrangements are made for illuminating with lights of different colors, and for observing, when occasion requires, with bright threads upon a bright field. The levels are boxed, provided with air-chambers, and read from end to end, not from the middle outwards.

In fine, it has been my endeavor to incorporate in the design of this instrument the principle, — never before attained, so far as I am aware, — that every instrumental correction, without exception, should be capable of determination by two entirely distinct and independent methods; and in this respect also to combine the advantages of the German and the English forms. And I may claim for the new instrument that its errors of graduation, its errors of flexure, collimation, level, azimuth and nadir-point, may all be determined by two separate processes, free from any dependence, direct or indirect, upon each other. And whatever may be its errors of construction or of mounting, there is no fear

that they will escape detection and accurate measurement. So earnest has been my desire to lose none of the advantages on either side of questions upon which experienced astronomers differ in opinion, that no point of detail has been deemed too minute for the application of this idea of duality, and I have even requested the artists to provide one set of microscopes with crosses, after the fashion of Troughton, and the other with close parallel threads, according to the custom of Repsold and the almost universal usage of the German mechanicians.

If this eclectic spirit shall prove to have been successful in attaining its ends without the sacrifice of unity, of artistic or theoretic elegance, of convenience, or of any scientific advantage, the care and labor bestowed upon the decision of the principles which should rule its design will be more than rewarded. But here, as in all instruments of a high order, it is the mechanical artist to whom most of the success is due, and to whose refined delicacy of judgment, taste, and skill we must thank the chief advances of modern astronomy. Bessel once said that he could determine the place of a star with a musket-barrel and a cart-wheel. Few things were impossible to Bessel, but you will agree with me that at any rate even a Bessel would with such appliances hardly have determined so large a number of precise star-positions as, thanks to the genius of Fraunhofer, Reichenbach and Repsold, are contained in those noble Königsberg volumes, and are sufficient to render the names of the artist and the astronomer alike immortal.

It is my privilege, on this occasion, to become the organ of the Trustees of the Observatory in announcing that, at the instigation of the Scientific Council, they have given to the new meridian-circle which I have been describing, — which, in the grandeur of its dimensions, is rivaled only by the renowned and gigantic transit-circle of the Royal Observatory at Greenwich, and which, as we are trusting, may prove to be a forward step in instrumental astronomy, — a name which will render the exquisite instrument still more a source of pride to Albany and to the Dudley Observatory, — a name full of associations of disinterested and unassuming liberality, of generous public spirit, — the name of a man who knows no guile, a citizen of large, expanded mind and heart, whose efforts have, under the blessing of a favoring Providence, resulted in an affluence by which all around him are made happy, and without whose constant effort, protecting care, and wise counsel, neither this instrument, nor the Observatory for which it is

designed, would ever have existed. The Trustees have authorized me to announce, that, in token of their respect for Thomas W. Olcott, of Albany, the instrument will be known as the OLCOTT Meridian-Circle, and that the name is already engraved upon the telescope at Berlin.

The transit-instrument is similar to the meridian-circle, so far as the latter is an instrument for the measurement of right ascension. It is the property of the Coast Survey of the United States, whose enlightened chief has authorized its employment at the Dudley Observatory for the present. The object-glass has a clear aperture of 72 French lines, and a focal length of 8 feet.

In both these instruments the Ys are so constructed that the level-arm may rest upon that part of the pivot which supports the instrument.

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## III. PHYSICS AND CHEMISTRY.

### 1. ON ACOUSTICS APPLIED TO PUBLIC BUILDINGS. By PROFESSOR JOSEPH HENRY, of Washington, D. C.

AT the meeting of the American Association in 1854, I gave a verbal account of a plan of a lecture-room adopted for the Smithsonian Institution, with some remarks on Acoustics as applied to apartments intended for public speaking. At that time the room was not finished, and experience had not proved the truth of the principles on which the plan had been designed. Since then the room has been employed two winters for courses of lectures to large audiences; and I believe it is the general opinion of those who have been present, that the arrangements for seeing and hearing, considering the size of the apartment, are entirely unexceptionable. The room has fully answered all the expectations which were formed in regard to it, previous to its construction. The origin of the plan was as follows.

Professor Bache and myself had directed our attention to the subject of acoustics as applied to buildings, and had studied the peculiarities in this respect of the hall of the House of Representatives, when the President of the United States referred to us for examination the plans proposed by Captain Meigs of the Engineer Corps, U. S. A., for

the rooms about to be constructed under his direction in the new wings of the Capitol. After visiting with Captain Meigs the principal halls and churches of the cities of Philadelphia, New York, and Boston, we reported favorably on the general plans proposed by him, and which were subsequently adopted.

The facts which we have collected on this subject may be referred to a few well-established principles of acoustics, which have been applied in the construction of the Smithsonian lecture-room. To apply them generally, however, in the construction of public halls, required a series of preliminary experiments.

In a very small apartment it is an easy matter to be heard distinctly at every point; but in a large room, unless from the first, in the original plan of the building, provision be made, on acoustic principles, for a suitable arrangement, it will be difficult, and indeed in most cases impossible, to produce the desired effect. The same remark may be applied to lighting, heating, and ventilation, and to all the special purposes to which a particular building is to be applied. I beg, therefore, to make some preliminary remarks on the architecture of buildings, bearing upon this point, which, though they may not meet with universal acceptance, will, I trust, commend themselves to the common sense of the public in general.

In the erection of a building, the uses to which it is to be applied should be clearly understood, and provision definitely made, in the original plan, for every desired object.

Modern architecture is not, like painting or sculpture, a fine art, *par excellence.* The object of these latter is to produce a moral emotion, — to awaken the feelings of the sublime and the beautiful; and we greatly err when we apply their productions to a merely utilitarian purpose. To make a fire-screen of Rubens's Madonna, or a candelabrum of the Apollo of Belvidere, would be to debase those exquisite productions of genius, and do violence to the feelings of the cultivated lover of art. Modern buildings are made for other purposes than artistic effect, and in them the æsthetical must be subordinate to the useful; though the two may coexist, and an intellectual pleasure be derived from a sense of adaptation and fitness, combined with a perception of harmony of parts, and the beauty of detail.

The buildings of a country and an age should be ethnological expressions of the wants, habits, arts, and feelings of the time in

which they were erected. Those of Egypt, Greece, and Rome were intended, at least in part, to transmit to posterity, without the art of printing, an idea of the character of the periods in which they were erected. It was by their monuments that these nations sought to convey an idea of their religious and political sentiment to future ages.

The Greek architect was untrammelled by any condition of utility. Architecture was with him in reality a fine art. The temple was formed to gratify the tutelar deity. Its minutest parts were exquisitely finished, since nothing but perfection on all sides and in the smallest particulars could satisfy an all-seeing and critical eye. It was intended for external worship, and not for internal use. It was without windows, entirely open to the sky, or, if closed with a roof, the light was merely admitted through a large door. There were no arrangements for heating or ventilation. The uses, therefore, to which, in modern times, buildings of this kind can be applied, are exceedingly few; and though they were objects of great beauty, and fully realized the intention of the architect by whom they were constructed, yet they cannot be copied in our day without violating the principles which should govern architectural adaptation.

Every vestige of ancient architecture which now remains on the face of the earth should be preserved with religious care; but to servilely copy these, and to attempt to apply them to the uses of our day, is as preposterous as to endeavor to harmonize the refinement and civilization of the present age with the superstition and barbarity of the times of the Pharaohs. It is only when a building expresses the dominant sentiment of an age, when a perfect adaptation to its use is joined to harmony of proportions and an outward expression of its character, that it is entitled to our admiration. It has been aptly said, that it is one thing to adopt a particular style of architecture, but a very different one to *adapt* it to the purpose intended.

Architecture should change not only with the character of the people, and in some cases with the climate, but also with the material to be employed in construction. The use of iron and of glass requires an entirely different style from that which sprung from the rocks of Egypt, the masses of marble with which the lintels of the Grecian temples were formed, or the introduction of brick by the Romans.

The great tenacity of iron, and its power of resistance to crushing,

should suggest for it, as a building material, a far more slender and apparently lighter arrangement of parts. An entire building of iron, fashioned in imitation of stone, might be erected at small expense of invention on the part of the architect, but would do little credit to his truthfulness or originality. The same may be said of our modern pasteboard edifices, in which, with their battlements, towers, pinnacles, "fretted roofs and long drawn aisles," cheap and transient magnificence is produced by painted wood or decorated plaster. I must not, however, indulge in remarks of this kind, but must curb my feelings on the subject, since I speak from peculiar experience.

But to return to the subject of acoustics, as applied to apartments intended for public speaking. While sound, in connection with its analogies to light, and in its abstract principles, has been investigated within the last fifty years with a rich harvest of results, few attempts have been successfully made to apply these principles to practical purposes. Though we may have a clear conception of the simple operation of a law of nature, yet when the conditions are varied, and the actions multiplied, the results frequently transcend our powers of logic, and we are obliged to appeal to experiment and observation to assist in deducing new consequences, as well as to verify those which have been arrived at by mathematical deduction. Furthermore, though we may know the manner in which a cause acts to produce a given effect, yet in all cases we are obliged to resort to actual experiment to ascertain the measure of effect under given conditions.

The science of acoustics as applied to buildings, perhaps more than any other, requires this union of scientific principles with experimental deductions. While, on the one hand, the application of simple deductions from the established principles of acoustics would be unsafe from a want of knowledge of the constants which enter into our formulæ, on the other hand, empirical data alone are, in this case, entirely at fault, and of this any person may be convinced who will examine the several works written on acoustics by those who are deemed practical men.

Sound is a motion of matter capable of affecting the ear with a sensation peculiar to that organ. It is not in all cases simply a motion of the air, for there are many sounds in which the air is not concerned; for example, the impulses which are conveyed along a rod of wood from a tuning-fork to the teeth. When a sound is produced by a

single impulse, or an approximation to a single impulse, it is called a noise; when by a series of impulses, a continued sound, &c.; if the impulses are equal in duration among themselves, a musical sound. This has been illustrated by a quill striking against the teeth of a wheel in motion. A single impulse from one tooth is a noise, from a series of teeth in succession a continued sound; and if all the teeth are at equal distances, and the velocity of the wheel is uniform, then a musical note is the result. Each of these sounds is produced by the human voice, though they apparently run into each other. Usually, however, in speaking, a series of irregular sounds of short duration are emitted, — each syllable of a word constitutes a separate sound of appreciable duration, and each compound word and sentence an assemblage of such sounds. It is astonishing, that, in listening to a discourse, the ear can receive so many impressions in the space of a second, and that the mind can take cognizance of and compare them.

That a certain force of impulse, and a certain time for its continuance, are necessary to produce an audible impression on the ear, is evident; but it may be doubted whether the impression of a sound on this organ is retained appreciably longer than the continuance of the impulse itself; certainly it is not retained the $\frac{1}{10}$th of a second. If this were the case, it is difficult to conceive why articulated discourse, which so pre-eminently distinguishes man from the lower animals, should not fill the ear with a monotonous hum; but whether the ear continues to vibrate, or whether the impression remains a certain time on the sensorium, it is certain that no sound is ever entirely instantaneous, or the result of a single impression, particularly in enclosed spaces. The impulse is not only communicated to the ear, but to all bodies around, which, in turn, themselves become centres of reflected impulses. Every impulse must give rise to a forward, and afterwards to a return, or backward, motion of the atom.

Sound from a single explosion in air, equally elastic on all sides, tends to expand equally in every direction; but when the impulse is given to the air in a single direction, though an expansion takes place on all sides, yet it is much more intense in the line of the impulse. For example, the impulse of a single explosion, like that of the detonation of a bubble of oxygen and hydrogen, is propagated equally in all directions, while the discharge of a cannon, though heard on every side, is much louder in the direction of the axis; so also

a person speaking is heard much more distinctly directly in front than at an equal distance behind. Many experiments have been made on this point, and I may mention those repeated in the open space in front of the Smithsonian Institution. In a circle, 100 feet in diameter, the speaker in the centre, and the hearer in succession at different points of the circumference, the voice was heard most distinctly directly in front, gradually less so on either side, until, in the rear, it was scarcely audible. The ratio of distance for distinct hearing directly in front, on the sides, and in the rear, was about as 100, 75, and 30. These numbers may serve to determine the form in which an audience should be arranged in an open field, in order that those on the periphery of the space may all have a like favorable opportunity of hearing, though it should not be recommended as the interior form of an apartment, in which a reflecting wall would be behind the speaker.

The impulse producing sound requires time for its propagation, and this depends upon the intensity of repulsion between the atoms, and, secondly, on the specific gravity of the matter itself. If the medium were entirely rigid, sound would be propagated instantaneously; the weaker the repulsion between the atoms, the greater will be the time required to transmit the motion from one to the other; and the heavier the atoms, the greater will be the time required for the action of a given force to produce in them a given amount of motion. Sound also, in meeting an object, is reflected in accordance with the law of light, making the angle of incidence equal to the angle of reflection. The tendency, however, to divergency in a single beam of sound, appears to be much greater than in the case of light. The law, nevertheless, appears to be definitely followed in the case of all beams that are reflected in a direction near the perpendicular. It is on the law of propagation and reflection of sound that the philosophy of echo depends. Knowing the velocity of sound, it is an easy matter to calculate the interval of time which must elapse between the original impulse and the return of the echo. Sound moves at the rate of 1125 feet in a second, at the temperature of 60°.*

* From the average of all the experiments, according to Sir John Herschel, the velocity of sound is 1090 feet at the temperature of 32°, and this is increased 1.14 feet for every degree of temperature of Fahrenheit's scale.

If, therefore, we stand at half this distance before a wall, the echo will return to us in one second. It is, however, a fact known from universal experience, that no echo is perceptible from a near wall, though in all cases one must be sent back to the ear. The reason of this is, that the ear cannot distinguish the difference between similar sounds, as, for example, that from the original impulse and its reflection, if they follow each other at less than a given interval, which can only be determined by actual experiment; and as this is an important element in the construction of buildings, the attempt was made to determine it with some considerable degree of accuracy. For this purpose the observer was placed immediately in front of the wall of the west end of the Smithsonian building, at the distance of 100 feet; the hands were then clapped together. A distinct echo was perceived; the difference between the time of the passage of the impulse from the hand to the ear, and that from the hand to the wall and back to the ear, was sufficiently great to produce two entirely distinct impressions. The observer then gradually approached the building, until no echo or perceptible prolongation of the sound was observed. By accurately measuring this distance, and doubling it, we find the interval of space within which two sounds may follow each other without appearing separately. But if two rays of sound reach the ear after having passed through distances the difference between which is greater than this, they produce the effect of separate sounds. This distance we have called the *limit of perceptibility* in terms of space. If we convert this distance into the velocity of sound, we ascertain the limit of perceptibility in time.

In the experiment first made with the wall, a source of error was discovered in the fact that a portion of the sound returned was reflected from the cornice under the eaves, and as this was at a greater distance than the part of the wall immediately perpendicular to the observer, the moment of the cessation of the echo was less distinct. In subsequent experiments with a louder noise, the reflection was observed from a perpendicular surface of about 12 feet square, and from this more definite results were obtained. The limit of the distance in this case was about 30 feet, varying slightly, perhaps, with the intensity of the sound and the acuteness of different ears. This will give about the sixteenth part of a second as the limit of time necessary for the ear to separately distinguish two similar sounds. From

this experiment we learn that the reflected sound may tend to strengthen the impression, or to confuse it, according as the difference of time between the two impressions is greater or less than the limit of perceptibility. An application of the same principle gives us the explanation of some phenomena of sound which have been considered mysterious. Thus, in the reflection of an impulse from the edge of a forest of trees, each leaf properly situated within a range of 30 feet of the front plane of reflection will conspire to produce a distinct echo, and these would form the principal part of the reflecting surfaces of a dense forest, for the remainder would be screened; and being at a greater distance, any ray which might come from them would serve to produce merely a low continuation of the sound.

On the same principle, we may at once assert that the panelling of a room, or even the introduction of reflecting surfaces at different distances, will not prevent the echo, provided they are in parallel planes, and situated, relatively to each other, within the limit of perceptibility.

Important advantage may be taken of the principle of reflection of sound by the proper arrangement of the reflecting surfaces behind the speaker. We frequently see in churches, as if to diminish the effect of the voice of the preacher, a mass of drapery placed directly in the rear of the pulpit. However important this may be in an æsthetical point of view, it is certainly at variance with correct acoustic arrangements, — the great object of which should be to husband every articulation of the voice, and to transmit it unmingled with other impulses, and with as little loss as possible, to the ears of the audience.

Another effect of the transmission and reflection of sound is that which is called reverberation, which consists of a prolonged musical sound, and is much more frequently the cause of indistinctness of perception of the articulations of the speaker than the simple echo.

Reverberation is produced by the repeated reflection of a sound from the walls of the apartment. If, for example, a single detonation takes place in the middle of a long hall with naked and perpendicular walls, an impulse will pass in each direction, will be reflected from the walls, cross each other again at the point of origin, be again reflected, and so on until the original impulse is entirely absorbed by the solid materials which confine it. The impression will be retained upon the ear during the interval of the transmission past it of two successive waves, and thus a continued sound will be kept up, particularly if the walls of any part

of the room are within 30 feet of the ear. If a series of impulses, such as that produced by the rapid snaps of a quill against the teeth of a wheel, be made in unison with the echoes, a continued musical sound will be the result. Suppose the wheel to be turned with such velocity as to cause a snap at the very instant the return echo passes the point at which the apparatus is placed, the second sound will combine with the first, and thus a loud and sustained vibration will be produced. It will be evident from this that every room has a key-note, and that, to an instrument of the proper pitch, it will resound with great force. It must be apparent, also, that the continuance of a single sound, and the tendency to confusion in distinct perception, will depend on several conditions; — first, on the size of the apartment; secondly, on the strength of the sound or the intensity of the impulse; thirdly, on the position of the reflecting surfaces; and fourthly, on the nature of the material of the reflecting surfaces.

In regard to the first of these, — the larger the room, the longer time will be required for the impulse along the axis to reach the wall; and if we suppose that at each collision a portion of the original force is absorbed, it will require double the time to totally extinguish it in a room of double the size, because, the velocity of sound being the same, the number of collisions in a given time will be inversely as the distance through which the sound has to travel.

Again, that it must depend upon the loudness of the sound, or the intensity of the impulse, must be evident, when we consider that the cessation of the reflections is due to the absorption of the walls, or to irregular reflection, and that, consequently, the greater the amount of original disturbance, the longer will be the time required for its complete extinction. This principle was abundantly shown by our observations on different rooms.

Thirdly, the continuance of the resonance will depend upon the position of the reflecting surfaces. If these are not parallel to each other, but oblique, so as to reflect the sound, not to the opposite, but to the adjacent wall, without passing through the longer axis of the room, it will evidently be sooner absorbed. Any obstacle, also, which may tend to break up the wave, and interfere with the reflection through the axis of the room, will serve to lessen the resonance of the apartment. Hence, though the panelling, the ceiling, and the introduction of a variety of oblique surfaces, may not prevent an isolated echo, provided

the distance be sufficiently great, and the sound sufficiently loud, yet that they do have an important effect in stopping the resonance is evident from theory and experiment. In a room 50 feet square, in which the resonance of a single intense sound continued six seconds, when cases and other objects were placed around the wall, its continuance was reduced to two seconds.

Fourthly, the duration of the resonance will depend upon the nature of the material of the wall. A reflection always takes place at the surface of a new medium, and the amount of this will depend upon the elastic force or power to resist compression and the density of the new medium. For example, a wall of nitrogen, if such could be found, would transmit nearly the whole of a wave of sound in air, and reflect but a very small portion; a partition of tissue-paper would produce nearly the same effect. A polished wall of steel, however, of sufficient thickness to prevent yielding, would reflect, for practical purposes, all the impulses through the air which might fall upon it. The rebound of the wave is caused, not by the oscillation of the wall, but by the elasticity and mobility of the air. The striking of a single ray of sound against a yielding board would probably increase the loudness of the reverberation, but not its continuance. On this point a series of experiments were made by the use of the tuning-fork. In this instrument, the motion of the foot and of the two prongs gives a sonorous vibration to the air, which, if received upon another tuning-fork of precisely the same size and form, would reproduce the same vibrations.

It is a fact well established by observation, that when two bodies are in perfect unison, and separated from each other by a space filled with air, vibrations of the one will be transmitted to the other. From this consideration, it is probable that relatively the same effect ought to be produced in transmitting immediately the vibration of a tuning-fork to a reflecting body, as to duration and intensity, as in the case of transmission through air. This conclusion is strengthened by floating a flat piece of wood on water in a vessel standing upon a sounding-board; placing a tuning-fork on the wood, the vibrations will be transmitted to the board through the water, and sounds will be produced of the same character as those emitted when the tuning-fork is placed directly upon the board.

A tuning-fork suspended from a fine cambric thread, and vibrated in air, was found, from the mean of a number of experiments, to con-

tinue in motion 252 seconds. In this experiment, had the tuning-fork been in a perfect vacuum, suspended without the use of a string, and, further, had there been no ethereal medium, the agitation of which would give rise to light, heat, electricity, or some other form of ethereal motion, the fork would have continued its vibration for ever.

The fork was next placed upon a large, thin pine board, — the top of a table. A loud sound in this case was produced, which continued less than *ten* seconds. The whole table as a system was thrown into motion, and the sound produced was as loud on the under side as on the upper side. Had the tuning-fork been placed against a partition of this material, a loud sound would have been heard in the adjoining room; and this was proved by sounding the tuning-fork against a door leading into a closed closet. The sound within was apparently as loud as that without.

The rapid decay of sound in this case was produced by so great an amount of the motive power of the fork being communicated to a large mass of wood. The increased sound was due to the increased surface. In other words, the shortness of duration was compensated for by the greater intensity of effect produced.

The tuning-fork was next placed upon a circular slab of marble, about three feet in diameter and three quarters of an inch thick. The sound emitted was feeble, and the undulations continued *one hundred and fifteen* seconds, as deduced from the mean of six experiments.

In all these experiments, except the one in a vacuum, the time of the cessation of the motion of the tuning-fork was determined by bringing the mouth of a resounding cavity near the end of the fork; this cavity, having previously been adjusted to unison with the vibrations of the fork, gave an audible sound when none could be heard by the unaided ear.

The tuning-fork was next placed upon a cube of India-rubber, and this upon the marble slab. The sound emitted by this arrangement was scarcely greater than in the case of the tuning-fork suspended from the cambric thread, and, from the analogy of the previous experiments, we might at first thought suppose the time of duration would be great; but this was not the case. The vibrations continued only about forty seconds. The question may here be asked, What became of the impulses lost by the tuning-fork? They were neither transmitted through the India-rubber, nor given off to the air in the form of

sound, but were probably expended in producing a change in the matter of the India-rubber, or were converted into heat, or both. Though the inquiry did not fall strictly within the line of this series of investigations, yet it was of so interesting a character in a physical point of view to determine whether heat was actually produced, that the following experiment was made.

A cylindrical piece of India-rubber, about an inch and a quarter in diameter, was placed in a tubulated bottle with two openings, one near the bottom and the other at the top. A stuffing-box was attached to the upper, through which a metallic stem, with a circular foot to press upon the India-rubber, was made to pass air-tight. The lower tubular was closed with a cork, in a perforation of which a fine glass tube was cemented. A small quantity of red ink was placed in the tube to serve as an index. The whole arrangement thus formed a kind of air-thermometer, which would indicate a certain amount of change of temperature in the enclosed air. On the top of the stem, the tuning-fork was screwed, and consequently its vibrations were transmitted to the rubber within the bottle. The glass was surrounded with several coatings of flannel, to prevent the influence of external temperature. The tuning-fork was then sounded, and the vibrations were kept up for some time. No reliable indications of an increase of temperature were observed. A more delicate method of making the experiment next suggested itself. The tube containing the drop of red ink, with its cork, was removed, and the point of a compound wire formed of copper and iron was thrust into the substance of the rubber, while the other ends of the wire were connected with a delicate galvanometer. The needle was suffered to come to rest, the tuning-fork was then vibrated, and its impulses transmitted to the rubber. A very perceptible increase of temperature was the result. The needle moved through an arc of from one to two and a half degrees. The experiment was varied, and many times repeated; the motions of the needle were always in the same direction, namely, in that which was produced when the point of the compound wire was heated by momentary contact with the fingers. The amount of heat generated in this way is, however, small, and indeed, in all cases in which it is generated by mechanical means, the amount evolved appears very small in comparison with the labor expended in producing it. Jule has shown that the mechanical energy generated in a pound weight, by

falling through a space of seven hundred and fifty feet, elevates the temperature of a pound of water one degree.

It is evident that an object like India-rubber actually destroys a portion of the sound, and hence, in cases in which entire non-conduction is required, this substance can probably be employed with perfect success.

The tuning-fork was next pressed upon a solid brick wall, and the duration of vibration from a number of trials was eighty-eight seconds. Against a wall of lath and plaster the sound was louder, and continued only eighteen seconds.

From these experiments we may infer that, if a room were lined with wainscot of thin boards, and a space left between the wall and the wood, the loudness of the echo of a single noise would be increased, while the duration of the resonance would be diminished. If, however, the thin board were glued or cemented in solid connection to the wall, or embedded in the mortar, then the effect would be a feeble echo, and a long continued resonance, similar to that from the slab of marble. This was proved by first determining the length of continuance of the vibrations of a tuning-fork on a thin board, which was afterwards cemented to a flat piece of marble.

A series of experiments were next commenced with reference to the actual reflection of sound. For this purpose a parabolic mirror was employed, and the sound from a watch received on the mouth of a hearing-trumpet, furnished with a tube for each ear. The focus was near the apex of the parabola, and when the watch was suspended at this point, it was six inches within the plane of the outer circle of the mirror. In this case the sound was confined at its origin, and prevented from expanding. No conjugate focus was produced, but, on the contrary, the rays of light, when a candle was introduced, constantly diverged. The ticking of the watch could not be heard at all when the ear was applied to the outside of the mirror, while directly in front it was distinctly heard at the distance of thirty feet, and with the assistance of the ear-trumpet, at more than double that distance. When the watch was removed from the focus, the sound ceased to be audible. This method of experimenting admits of considerable precision, and enables us directly to verify, by means of sound transmitted through air, the results anticipated in the previous experiments. A piece of tissue-paper placed within the mirror, and

surrounding the watch without touching it, slightly diminished the reflection. A single curtain of flannel produced a somewhat greater effect, though the reflecting power of the metallic parabola was not entirely masked by three thicknesses of flannel; and, I presume, very little change would have been perceived, had the reflector been lined with flannel glued to the surface of the metal. The sound was also audible at the distance of ten feet, when a large felt hat, without stiffening, was interposed between the watch and the mirror. Care was taken in these experiments so to surround the watch, that no ray of sound could pass directly from it to the reflecting surface.

With a cylindrical mirror, having a parabolic base, very little increased reflection was perceived. The converging beams in this case were merely in a single plane, perpendicular to the mirror, and passing through the ear, while to the focal point of the spherical mirror a solid cone of rays was sent.

The reflection from the cylindrical mirror forms what is called a *caustic* in optics, while that from a spherical mirror gives a true focus, or, in other words, collects the sounds from all parts of the surface, and conveys them to one point of space. These facts furnish a ready explanation of the confusion experienced in the Hall of Representatives, which is surmounted by a dome, the under surface of which acts as an immense concave mirror, reflecting to a focus every sound which ascends to it, leaving other points of space deficient in sonorous impulses.

Water, and all liquids which offer great resistance to compression, are good reflectors of sound. This may be shown by the following experiment. When water is gradually poured into an upright cylindrical vessel, over the mouth of which a tuning-fork is vibrated, until it comes within a certain distance of the mouth, it will reflect an echo in unison with the vibrations of the fork, and produce a loud resonance. This result explains the fact, which had been observed with some surprise, that the duration of the resonance of a newly plastered room was not perceptibly less than that of one which had been thoroughly dried.

There is another principle of acoustics which has a bearing on this subject. I allude to the refraction of sound. It is well known that, when a ray of sound passes from one medium to another, a change in velocity takes place, and consequently a change in the direction or a

refraction, must be produced. The amount of this can readily be calculated where the relative velocities are known. In rooms heated by furnaces, and in which streams of heated air pass up between the audience and speaker, a confusion has been supposed to be produced, and distinct hearing interfered with, by this cause. Since the velocity of sound in air at 32° of Fahrenheit has been found to be 1090 feet in a second, and since the velocity increases 1.14 feet for every degree of Fahrenheit's scale, if we know the temperature of the room, and that of the heated current, the amount of angular refraction can be ascertained. But since the ear does not readily judge of the difference of direction of two sounds emanating from the same source, and since two rays do not confuse the impression which they produce upon the ear, though they arrive by very different routes, provided they are within the limit of perceptibility, we may therefore conclude that the indistinctness produced by refraction is comparatively little. Professor Bache and myself could perceive no difference in distinctness in hearing from rays of sound passing over a chandelier of the largest size, in which a large number of gas jets were in full combustion. The fact of disturbance from this cause, however, if any exist, may best be determined by the experiment with a parabolic mirror and the hearing-trumpet before described.

These researches may be much extended: they open a field of investigation equally interesting to the lover of abstract science and to the practical builder; and I hope, in behalf of the committee, to give some further facts with regard to this subject at another meeting.

I will now briefly describe the lecture-room which has been constructed in accordance with the facts and principles previously stated, so far at least as they could be applied.

There was another object kept in view in the construction of this room besides the accurate hearing, namely, the distinct seeing. It was desirable that every person should have an opportunity of seeing the experiments which might be performed, as well as of hearing distinctly the explanation of them.

By a fortunate coincidence of principle, it happens that the arrangements for insuring unobstructed sight do not interfere with those necessary for distinct hearing.

The law of Congress authorizing the establishment of the Smithsonian Institution directed that a lecture-room should be provided; and

accordingly in the first plan one half of the first story of the main building was devoted to this purpose. It was found, however, impossible to construct a room on acoustic principles in this part of the building, which was necessarily occupied by two rows of columns. The only suitable place which could be found was therefore on the second floor. The main building is two hundred feet long and fifty feet wide; but by placing the lecture-room in the middle of the story a greater width was obtained by means of the projecting towers. The general form and arrangement of the room will be understood from the accompanying drawing.

It is one hundred feet from A to B, and on the ground floor seventy-five feet from C to D. E F represents a small gallery in a projection into the rear tower. The main gallery is in the form of a horseshoe, and occupies three sides of the room. The speaker's platform is placed between two oblique walls, H I J K. The corners of the room which are cut off by these walls afford recesses for the stairs into the galleries. The opposite corners are also partitioned off, so as to afford recesses for the same purpose.

The ceiling is twenty-five feet high, and therefore within the limit of perceptibility. It is perfectly smooth and unbroken, with the exception of an oval opening nearly over the speaker's platform, through which light is admitted.

The seats are arranged in curves, and were intended to rise in accordance with the *panoptic curve*, originally proposed by Professor Bache, which enables each individual to see over the head of the person immediately in front of him. The original form of the room, however, did not allow of this intention being fully realized, and therefore the rise is somewhat less than the curve would indicate. The general appearance of the room is somewhat fan-shaped, and the speaker is placed as it were in the mouth of an immense trumpet. The sound directly from his voice, and that from reflection immediately behind him, is thrown forward upon the audience; and as the difference of distance travelled by the two rays is much within the limit of perceptibility, no confusion is produced by direct and reflected sound.

No echo is given off from the ceiling, for this is also within the limit of perceptibility, while it assists the hearing in the gallery by the reflection to that place of the oblique rays.

Again, on account of the oblique walls behind the speaker, and the multitude of surfaces, including the gallery, pillars, stair-screens, &c., as well as the audience, directly in front, all reverberation is stopped.

The walls behind the speaker are composed of lath and plaster, and therefore have a tendency to give a more intense, though less prolonged, sound than if of solid masonry. They are also intended for exhibiting drawings to the best advantage.

The architecture of this room is due to Captain Alexander, of the corps of Topographical Engineers. He fully appreciated all the principles of sound which I have given, and varied his plans until all the required conditions, as far as possible, were fulfilled.

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## 2. Account of a large Sulphuric-Acid Barometer in the Hall of the Smithsonian Institution. By Professor Joseph Henry, of Washington, D. C.

The opinion has been frequently advanced, that a barometer in which the material used to balance the pressure of the atmosphere is of less specific gravity than mercury, and consequently of a wider range of fluctuation, might throw some new light on several important points of Meteorology. The fluid usually proposed for this purpose has been oil or water; the viscid character of the former, and its tendency to a change of condition, has induced a preference for the latter. Several water-barometers have accordingly been constructed; but, as far as I am informed, the indications of the instruments have not been reliable.

Mariotte used one of this character; also Otto von Guericke constructed a philosophical toy, to which he gave the name of anemoscope, or *semper virum*, on the principle of a water-barometer. It consisted of a tube more than thirty feet high, elevated on a long wall, and terminated by a tall and rather wide glass cylinder, hermetically sealed, in which was placed a toy in the shape of a man. All the tube except a portion of the cylindrical part was concealed behind the wainscoting, and consequently the little image made its appearance only in fine weather.

A water-barometer was constructed by Professor Daniell, and

placed in the hall of the Royal Society, of which a full account has been published in the Transactions of that institution. A minute account is given of the method of blowing the tube, and the details of permanently fastening it in the box which was to form the case. The tube was left open at both ends; to the upper one a stop-cock was attached, and the lower one was inserted in a small steam-boiler, which served the purpose of boiling the water, to expel all the air, of elevating it to the proper height by means of the elastic force of the steam, and also as a permanent cistern to the barometer. After the water was forced to the top and issued from the stop-cock in a jet, the latter was closed; the stop-cock in the boiler was opened, steam suffered to escape, and the water to settle in the tube until balanced by the pressure of air. The upper part of the glass under the stop-cock, which had previously been drawn out into a fine tube, was gradually heated by a blow-pipe, and as soon as it was sufficiently softened the pressure of the air effectually closed it. The part above the stop-cock was then removed with a file. This barometer was completed, after adjusting the scale, by pouring a quantity of castor-oil on the surface of the water to prevent contact with the air.

After a series of observations, however, it was found in the course of about three months that the column of water was gradually descending, and it was finally resolved to open the boiler and to examine the instrument. The oil upon the surface was found to have undergone a change, though the water below was perfectly bright and transparent. A portion of the water was taken out and placed under the receiver of an air-pump, and bubbles of air in abundance were extricated; the air was absorbed by the water, diffused through the whole mass to the top, where it was given off to the vacuum, and thus caused the gradual descent of the column. It was however found it was not atmospheric air in the vacuum, but nearly pure nitrogen; the oxygen had been absorbed in passing through the oil, producing rancidity and other changes in that liquid.

It was evident from this experiment, that oil was not impervious to air. Another attempt to remedy this defect of the instrument was made by using a thin film of gutta-percha, to be left after the evaporation of the naphtha in which it had been dissolved.

An objection, however, to the use of water as the liquid for the barometer, is the vapor which it always gives off, and of which the tension cannot readily be determined. In a glass vessel, in which a

cup of water is enclosed, Professor Espy informs me that he has found the dew-point always less than that which would be due to the temperature.

Desiring to fit up a barometer on a large scale, as one of the objects of interest and use in the Smithsonian Institution, I consulted my friend Professor Schaeffer of the Patent Office as to the best liquid to be employed. He advised the use of sulphuric acid, but I did not immediately adopt this advice, on account of the apparently dangerous character of this substance. Happening, however, some time afterwards to be speaking on the subject of barometers with Mr. James Green, the instrument-maker, in the presence of Professor Ellet of New York, the latter asked why I did not have a large one constructed with sulphuric acid. The suggestion having thus again been independently made, and Mr. Green expressing his willingness to undertake the work, I gave the order for the construction of the instrument, and requested Professor Ellet to give any suggestions as to the details which might be required.

The advantages of this liquid are: — 1. That it gives off no appreciable vapor at any atmospheric temperature; and 2. That it does not absorb or transmit air. The objections to its use are: — 1. The liability to accident from the corrosive nature of the liquid, either in the filling of the tube or in its subsequent breakage; and, 2. Its affinity for moisture, which tends to produce a change in specific gravity. The filling, however, is a simple process, and attended with but little, if any, risk. The acid can gradually be poured into the tube while in its case, slightly inclined to the horizon. Any accident from breakage can be prevented by properly securing the whole instrument in an outer case, which will also serve to equalize the temperature. To prevent the absorption of moisture, the air may be previously passed through a drying tube apparatus. The only point in which water would be preferable to sulphuric acid is the less specific gravity of the former, and consequently the greater range of its fluctuation, which is as 20 : 11, nearly.

The general appearance of the instrument, and the several contrivances for adjustment and reading, are in accordance with the reputation of the skilful and intelligent artist who made it. The glass tube is two hundred and forty inches long, and three fourths of an inch in diameter, and is enclosed in a cylindrical brass case of the same length, and two and a half inches in diameter. The glass tube is se-

cured in the axis of the brass case by a number of cork collars, placed at intervals; which, while they prevent all lateral displacement of the tube, enable it to be moved upwards and downwards for the adjustment of the zero-point.

The reservoir consists of a cylindrical glass bottle, of four inches in diameter, with two openings at the top; one in the axis to admit the lower end of the long tube, which is tapered to about one half of the general diameter, the other to transmit the varying pressure of the atmosphere.

To adjust the zero-point, the whole glass part of the apparatus, together with the contained acid, is elevated or depressed by a screw, placed under the bottom, until the level of the acid in the reservoir coincides with a fixed mark.

The scale for reading the elevation is divided into inches and tenths, and by means of a vernier, moved by a rack and pinion, the variations can be measured to a hundredth of an inch, and estimated to a still smaller division.

The vernier itself is not immediately attached to the cylindrical brass case, but to a sliding frame, which can be moved along the whole opening through which the entire range of the column is observed. The motion of the frame enables us to make the first rough adjustment, and that of the rack and pinion the minute one.

The drying apparatus, placed between the external air and the interior of the reservoir, consists of a tubulated bottle with two openings containing chloride of calcium, and connected with the reservoir by an India-rubber tube, by which arrangement the air is deprived of its moisture.

To ascertain the temperature of the column of the liquid, two thermometers are attached, one at the top and the other near the bottom.

The whole apparatus is enclosed in an outer glazed case of twelve inches square, which serves, as mentioned before, as well for protection as for equalizing the temperature, which is with sufficient accuracy ascertained by taking the mean of the two thermometers.

A large correction is required in this barometer for the expansion and contraction by the changes of temperature. To determine the amount of this, the specific gravity of a quantity of the acid with which the barometer had been filled was taken at different temperatures. This process was performed with a very sensitive balance, by Dr. Easter, in the laboratory of the Institution.

3. Some Experiments on Visual Direction. By Professor John Brocklesby, of Trinity College, Hartford, Ct.

Some years ago I met with a brief allusion to the existence of an "Essay on Single Vision," published by Dr. Woodhouse in the Philosophical Magazine. In this treatise, it seems, the author endeavors to prove from certain experiments and physiological considerations, that one eye is wholly occupied with vision, while the other is nearly or entirely passive. My attention was arrested by this inference, and as the essay, with its detailed experiments, was not accessible, I was led to make some investigations upon this point, and on others kindred to it. These investigations, and the conclusions to which they lead, are the subject of the present paper. It is well known, that if, while looking at a remote object with both eyes open, we interpose a second at a short distance from us, the latter will appear *double;* the image formed by the right eye being seen towards the left hand, and that formed by the left towards the right hand; the proximity of the images depending upon the magnitude of the interposed body, and its distance from the eyes. As we cannot, at the same time, range both the separate images of the nearest object with the remote one, and yet as a matter of fact we do in some way range objects thus situated, when both eyes are open, it follows that a solution of this point touches on the one in question. In order to ascertain in what manner I was enabled to range objects at different distances by double vision, I instituted the following personal experiments. How far the results obtained are to be regarded as general, will appear in the subsequent pages.

*Of the Range of a Point near the Eyes with an Object more or less remote.* — If, with both eyes open, I bring before me, beyond the limit of distinct vision, a small point like that of a pencil, and endeavor to range it with some object more or less remote, as a figure on a wall, or the ball of a spire, I find that two images of the point at once appear, but that the image seen by the *right eye* is immediately and involuntarily selected as that which ranges with the remote object. This is proved by the fact, that, if the left eye is closed, the range is still preserved; but if the right eye is closed, and the left remains open, the range is destroyed, the point being seen to the right of the distant object. Moreover, if, reversing the experiment, I first bring the

point and object in a line with the right eye alone, the left being closed, it is found that they continue in a range when both eyes are open, but that if the range is first taken with the left eye only, and the objects are then viewed with both eyes, the range ceases to exist; the point being seen to the left of the remote object. These changes in visual direction are more marked when the point is brought within the limit of distinct vision, and the second object is a few feet distant. Upon taking *two* or more points, instead of one, and ranging them with some object at a distance, the same results occur as in the former case. The optical effect, however, is more striking than when one point is used, and the power of the right eye to control the range is very evident.

*Range of a Straight Line.* — Since an infinite number of material points, placed one behind the other, so near as to touch, may be regarded as forming a straight line, it might be reasonably inferred that a *straight line* would present the same phenomena in respect to visual direction as a point, or any number of points. Experiment shows this inference to be correct, for, upon ranging a line, as the edge of a rule, with a second object, both eyes being open, the range, upon closing the left eye, is still maintained, but is lost when the right eye alone is closed; the edge in the last case not being seen in the direction of its length, but obliquely. If, also, as before, the range is first taken with the right eye, it is preserved when both eyes are open; but if with the left, it is apparently lost when viewed with both eyes.

*Range of a Surface.* — If similar experiments to those just detailed are made with a *surface* of small extent, the same prevailing power of the right eye to control the visual direction is still manifested, but is most strikingly exhibited when *several surfaces* are made to range with a fixed object. Thus, if a number of bright objects are taken, as the flames of several candles, the ruling power of the right eye is finely revealed, by first ranging the flames in a line with both eyes, and then beholding them with each eye alone.

*Range of a Solid.* — By the union of numerous material surfaces, equal each to each, and having their centres in the same straight line, solid cylinders and prisms may be formed, and the same law of visual direction that belongs to these surfaces belongs also to the solids that they compose. For if a small straight *rod* is sighted, in the direction of its length, with a second object, in the various ways that have been

mentioned, the range is the same when it is viewed in succession by the right eye and by both eyes; but different when the left is used instead of the right.

*Range of an Opening.* — If a ring is taken, or a card with an opening in it, and the card is so held that I look through the opening at some distant object, both eyes being open, the two images of the opening formed by the eyes are readily perceived, but it is only through that which belongs to the right eye that the object is seen; for if the left is closed, the object is still visible through the opening; but if the right is closed and the left is open, it is no longer seen through the orifice. If the range at first is taken with the right eye, there is no shifting of the visible direction of the object when both eyes are employed in vision, the left coming to the aid of the right. But when the range at the outset is taken with the left eye, and the right is then opened, the influence of the left eye upon the range is very feeble, and seems almost destroyed by the power of the right.

If, instead of one perforated card, two or three are employed at the same time, the object being viewed through the cards placed one behind the other, the influence of the right eye is rendered more evident. For when the object is first seen through the several openings with both eyes open, upon closing the right, not only does the object become invisible, but some of the openings also; for instance, I may see through the opening of the first card the unbroken face of the second, the orifice in the latter being out of sight.

*Range of a Tube.* — A tube may be regarded as composed of a number of *material* rings; it might therefore be expected to present the same visual phenomena as orifices and rings, and such is found to be the case upon looking through a tube at a distant object, in the different ways that have been mentioned.

By directing especial attention to the left eye, it may be made to control the range instead of the right, and objects can be seen by it in the same direction as when viewed by both eyes; but this control ceases with the particular effort of the will that calls the eye to discharge an unusual duty. On the other hand, in the normal condition of vision, when objects are viewed without any special exertion of the will, I find from the experiments detailed, that, on account of habit or otherwise, I invariably neglect the image formed by the left eye and take that belonging to the right; and that the visual direction of *points*, *lines*, *sur-*

*faces*, and *solids*, *near* to the observer, is always determined by the right eye.

But a question arises, Is this dominant power of the right eye a peculiarity of the individual, like Daltonism, or is it *generally* true? In reply, I would state that I have been accustomed for a length of time to propose some of the preceding experiments to different individuals, and the result has almost invariably been, that, when both eyes are open, the right eye determines the visual direction of near objects. Out of as many as seventy or eighty cases, not more than three or four exceptions from this rule have been detected. In one of these exceptions the right eye was weaker than the left, and the latter discharged the functions of the former in the aforesaid experiments, and *vice versa*. Another exception occurs in the case of a civil engineer, who is accustomed to sight objects with both eyes open, by glancing suddenly from one to the other. In this instance, the observer, when ranging a near object with a distant one, with both eyes open, finds the image of the former to be situated half-way between its two positions as beheld with each eye separately.

In view of these facts, I am inclined to believe that most persons, when they gaze upon a near object with both eyes open, habitually neglect the image formed by the left eye, and employ that of the right to fix the visual direction, — in fact, that we are *right-eyed*. Moreover, that cases sometimes occur where the left eye is used for this purpose, and in such exceptional instances the observers may be termed *left-eyed*.

A boy shoots marbles with both eyes open, and a sportsman not unfrequently brings down his game in the same manner; but I apprehend that in both instances the aim is as truly taken as if one eye was shut, and that either the right eye or the left gives the range, while the other is passive.

If it is true that the right eye, under the circumstances mentioned, possesses a superiority over the other, the fact would be in strict accordance with some other physiological phenomena. We are all aware of the pre-eminence which the right hand has over the left, either from habit or otherwise, — how much more ready and quick it is in all its motions, being the first to advance whenever the hand is needed. So marked is this characteristic, that we term expertness and activity of manipulation *dexterity*. Right-handedness constitutes

the law, left-handedness the exception. The same fact is observed in respect to the feet. In the game of football, for instance, the right foot naturally comes first into play, and is decidedly more active than the other. The superiority of one organ of vision over the other would not, therefore, constitute an anomaly; neither would it be surprising if the same phenomenon should be found to exist in respect to one or more of the other senses.

While making some of the preceding experiments, it occurred to me that there might possibly exist such a sympathy between the eyes and the hands that the right hand acts in unison with the right eye, and the left hand with the left eye; so that a left-handed person would be found to be left-eyed, and a right-handed right-eyed. In order to solve this point I had recourse to one who was a skilful blacksmith, and who used his left hand exclusively in wielding the hammer; but in this case it also happened, as in those of right-handed persons, that the right eye took precedence of the left, and the supposed unison of action did not exist.

Thus far, the visual direction of a *near* with a *distant* object has only been considered; but this point may be examined still further, both in reference to *two remote objects* and to the extent of range when we look through an opening. If a surface of considerable extent, as a board a foot wide or more, is placed at a moderate distance from the observer, for instance sixty or seventy feet, and this surface is projected upon the wall of a building at some distance behind, I find that the space on the building which the board conceals is not, as in the case of a near object, limited by the right eye, but is determined as follows. A line drawn from the *right eye* to the *right-hand edge* of the board and continued to the wall fixes, in the normal state of vision, the *right-hand limit* of the concealed portion of the wall; and a line drawn from the *left eye* to the *left-hand edge* of the board, and produced to the wall, determines also the *left-hand limit* of the hidden surface. For, having first projected the board upon the wall with both eyes, I find that, upon closing the right eye and viewing the board with the left, the right-hand edge shifts to the right, while the left-hand edge is unchanged in position; and that, when the right eye is open and the left closed, the left-hand edge shifts to the left, but the other edge keeps its first place. When therefore both eyes are open, the right controls the visual direction of the right edge of the board, and the left the left edge. This fact is still further proved by first

viewing the objects with each eye, and then with both. The horizontal visual angle, therefore, under which the surface is seen when both eyes are open, is less than that under which it is beheld with one eye, by the amount of the angle formed by drawing lines from each eye to one of the vertical edges.

A different rule appears to obtain in respect to the horizontal extent of view that occurs when we gaze through a large opening, as a window, upon the landscape before us. By experimenting, in the way already mentioned, I find the limit of vision to be thus determined. A line drawn from the *right eye* to the left-hand side of the window, and produced onward, gives the position of the *left-hand boundary* of the landscape; and another line drawn from the *left eye* to the *right-hand side* of the window determines the *right-hand* boundary of vision.

By comparing these results with those immediately preceding, it appears that, when a landscape is observed either through an opening or partially obscured by some intervening object, both eyes are employed in fixing the limits of vision, but in a different way, yet in such a manner that a greater extent is seen with two eyes than with one; in the first case, by increasing the visual angle of the landscape, and in the second, by reducing the visible angle of the obscuring object to a minimum.

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## 4. Redetermination of the Atomic Weight of Lithium. By Professor J. W. Mallet, of Alabama.

A review was taken of the previous determinations of the atomic weight of this element, from which it appeared that but two experiments deserving of confidence are on record, both of which were made by the same process, viz. the estimation of the sulphuric acid in sulphate of lithia by means of a salt of baryta. The extreme difficulty of removing by washing, from sulphate of baryta, the last traces of the salt of baryta used for precipitation, was pointed out as an objection to this process, the quantity of sulphuric acid apparently obtained being rendered too high, and the equivalent of lithia being therefore brought out less than the true number.

The results of three determinations of the chlorine contained in

chloride of lithium were then given, — the first and second experiments being made by precipitating a weighed quantity of this salt with nitrate of silver, and weighing the chloride of silver produced, — the third experiment consisting in the addition to a weighed quantity of Li Cl, dissolved in water, of the solution in nitric acid of a weighed quantity of pure silver (not sufficient for the complete precipitation of the chlorine), and the cautious addition to the liquid, from a graduated pipette, of a very dilute solution of nitrate of silver of known strength as long as a cloud was produced. The precautions necessary in the preparation of pure chloride of lithium were noticed.

The actual results obtained were, — 7.1885 grm. of Li Cl gave 24.3086 grm. of Ag Cl; 8.5947 grm. of Li Cl gave 29.0621 grm. of Ag Cl; and 3.9942 grm. of Li Cl required for precipitation 10.1702 grm. of Ag.

Hence the atomic weights, —

| | |
|---|---|
| 1st. | 86.93 |
| 2d. | 86.96 |
| 3d. | 86.78 |

or, as the mean, 86.89 on the oxygen scale, — a number decidedly higher than that previously adopted for lithium, but believed to be deserving of more confidence from the nature of the process pursued and the large quantity of the salt of lithia employed in the present determination.

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## 5. Ammonia in the Atmosphere. By Professor E. N. Horsford, of Cambridge.

At the New Haven meeting of the American Association in 1850, I submitted a paper upon the Ammonia in the Atmosphere, the conclusions of which, later research, in the course of the same year, satisfied me were radically erroneous. Before the meeting of 1851 I made a new series of determinations, extending from March 1st, down to June 20th, with every precaution to secure accuracy which I could devise. I felt, however, reluctant to publish the results without being able to show wherein the error of the previous research con-

sisted.* The source of error having since revealed itself, I ask to lay the correction before the Association.

The chief points noticed in the research of 1849 – 50 were the influence of the direction of the wind upon the quantities of ammonia observed in the air, and the large amount of ammonia. Both these supposed facts were based upon an error in the process, which I did not fairly and fully take into account until recently. I had removed the bottles containing ammonia compounds from the room in which the determinations were made, and had taken such other precautionary measures to insure reliable results as I could devise, but one important one escaped me.

To increase the extent of absorbing surface in the flasks employed, I spread over the interior flocculent asbesots. At the conclusion of each determination, the contents of the flasks, including the asbestos, were thrown upon a filter. This filter was washed till the wash-water gave no reaction with nitrate of silver. Meanwhile another portion of asbestos had been introduced into the flasks, and a new determination commenced. The first portion of asbestos, with the hydrochloric acid, which could not be entirely washed out, remained several days exposed to the air, absorbing ammonia from the atmosphere, and this asbestos was in its turn, *without ignition*, returned to the flasks, and of course contributed its ammonia in the form of chloride to the next determination. The paper-filter, too, was not renewed except at considerable intervals, and this, with its sal ammoniac, augmented the amount of error. It will be seen that the amounts of ammonia would be exponents of the temperature, and thus, to a certain extent, in keeping with the direction of the wind, which was one of the striking results in my former paper.

The general method observed in my second series was the same as in the first, and that which has been pursued by all who have made this class of determinations. A known volume of air was conducted through a series of flasks containing hydrochloric acid, by means of an aspirator.

My series consisted of six flasks, with slender necks, and of the shape and capacity of those used for determinations of chloride of sil-

* J. Pierre, the average of whose final determinations corresponds almost precisely with that of my last series, was unable to see wherein the error of his first determinations consisted.

ver. The flask nearest the aspirator contained water only. The tube from this flask to the next in succession dipped below the surface of the diluted hydrochloric acid which the flask contained. The next flask contained a little diluted hydrochloric acid. The next contained acid a little more concentrated; the next, a few drops of highly concentrated acid; and the next, water, under the surface of which passed the tube communicating with the preceding flask.

The aspirator was a cask of about twenty gallons' capacity. Of this description there were three, placed for convenience on little platforms mounted on castors. The water was permitted to flow slowly from a cock into a glass jar, the capacity of which in cubic centimetres to a point in the neck had been accurately ascertained.

Two determinations were usually carried forward simultaneously, in all respects under the same circumstances of arrangement, time, and quantity.

The capacity of the glass jars employed was 4260 cc. for each, and they were filled in all from 50 to 240 times for each determination. That is, the amount of air drawn through the aspirator was from $50 \times 4260 = 213{,}000$ cc. to $240 \times 4260 = 1{,}022{,}400$ cc.

At the conclusion of the process the flasks were carefully rinsed out, the contents poured upon a filter, and the filtrate carried down with a few drops of platinum solution over a water-bath nearly to dryness, the precipitate treated with alcohol, and brought on a weighed filter.

The first determination, on March 1st, gave for the platinum precipitate 0.0530 gr. for $50 \times 4260$ cc.

The next two made simultaneously for the same volume of air, on

$$\text{March 15th, gave } \left.\begin{array}{l} 1. = 0.0298 \text{ gr.} \\ 2. = 0.0584 \text{ ''} \end{array}\right\} \text{difference } 0.0286.$$

The next two, on

$$\text{March 30th, gave } \left.\begin{array}{l} 3. = 0.0570 \text{ ''} \\ 4. = 0.0594 \text{ ''} \end{array}\right\} \quad \text{''} \quad 0.0024.$$

The next two, on

$$\text{April 3d, gave } \left.\begin{array}{l} 5. = 0.0764 \text{ ''} \\ 6. = 0.0755 \text{ ''} \end{array}\right\} \quad \text{''} \quad 0.0009.$$

These great contrasts pointed to the necessity of observing many particulars in the mode of determination which in common quantitative analysis are usually dispensed with. The sources of error were various.

The quantity of distilled water employed in rinsing out the apparatus had not been invariably and precisely the same. The hydrochloric acid and bichloride of platinum had not been rigidly the same in quantity, and the amount of ammonia present in them, though once before ascertained, and found to be quite insignificant, was again determined, and found to be very considerable.

600 cc. of distilled water, and 20 cc. of hydrochloric acid, being *about* the quantity employed, and the usual quantity of platinum solution, were evaporated over a water-bath, and gave a precipitate of 0.0699 gr., which at once showed the preceding determinations to be of no value.

The following precautions and modifications were then adopted.

1st. The distilled water employed was prepared by slowly distilling from water to which sulphuric acid had been added.

2d. The hydrochloric acid was prepared in the usual manner, employing the above distilled water.

3d. The filters, hitherto dried in the common steam-chamber for an invariable length of time, were now dried in a Rammelsberg's desiccator for two hours, at a temperature not exceeding 100° C., and then for one half-hour at 120° C.

4th. The filter was dried and weighed in an arrangement of glass tubes, one sliding within the other, open while drying, and reversed and closed while weighing, so as effectually to prevent the absorption of moisture after the filter is once properly dried.

It was ascertained that the filter and the contents so confined did not vary in weight the amount of half a milligramme in three days.

It was also ascertained by two determinations that the weighed filter, after washing with alcohol, and subsequent drying, as above described, did not change its weight in the least.

When, after such drying, the weight had been determined, and after a heat at 120° for another half-hour had not changed it, in the amount of one tenth of a milligramme, it was considered dry.

5th. The quantity of water employed for washing out the flasks was accurately measured out, 600 cc. for each time.

6th. The evaporation was conducted under a sheet of filter-paper, to exclude dust. The last portions were evaporated at a temperature considerably below that of boiling water, as experience had shown that, without this precaution, some of the precipitate adhered to the sides of the evaporating-dish.

When the total residue consisted of only a few drops, alcohol was added.

7th. At the same time, and observing all the same precautions, a corresponding quantity of water, and the exact quantities of hydrochloric acid and platinum solution were evaporated down, and the precipitate (which still amounted to an appreciable quantity) determined and subtracted from the other.

8th. As the quantity of ammonia found proved to be much smaller than it had before seemed, it was decided, instead of fifty gallons of air, as heretofore, to run through the apparatus a much larger quantity. The water from the aspirator was run in the slenderest stream, considerably slower than before.*

With these precautions, determinations were commenced anew at a point uninfluenced by exhalation from any quarter.

1. The two determinations made side by side at the same time, with only 50 × 4260 cc., gave respectively of platinum precipitate,

April 25th, 1. 0.00180 gr. } difference 0.00055, average 0.002075.
2. 0.00235 "

The distilled water and reagents evaporated gave a visible trace of platinum precipitate; the weight of the filter with the precipitate after drying was, however, found smaller than that of the filter alone, by the amount of 0.0012 gr., owing to the thermometer having once risen above 120° C. Estimating the precipitate at one fourth of a milligramme by comparing it with subsequent determinations, and subtracting the weight from the above, 0.002075, gives 0.001825 as the average quantity for 1 and 2. This, for the sake of comparison, referred to 100 jars of water = 100 × 4260, gives 0.00365 gr. platinum precipitate.

* The following precautions may be serviceable to any who may care to repeat the determinations: —

1st. The paper used for filtering the acid rinsings should be renewed for each determination, as the acid, which it is quite impossible to remove entirely from the paper, absorbs ammonia from the air.

2d. The tubes employed for measuring the hydrochloric acid and platinum solution should be rinsed immediately after use.

3d. The filter tubes when taken from the drying-chamber should be left a quarter of an hour to cool before weighing.

4th. As the platinum precipitate is not absolutely insoluble in alcohol, the quantities employed should be measured, and the alcohol should be rectified.

2d Determination, March 1st, 100 × 4260 cc. of air gave of platinum precipitate,

3. 0.00290 gr. } difference 0.00035, average 0.00272 gr.
4. 0.00255 " }

The precipitate from the water and reagents was a mere trace.

3d Determination, May 18th, 100 × 4260 cc. of air gave of platinum precipitate,

5. 0.0078 gr. } difference 0.0006, average 0.0075.
6. 0.0072 " }

The precipitate from the water and reagents was 0.0010 gr., which subtracted from 0.0075 gr. gives the average of 5 and 6,

0.0065 gr.

4th Determination, May 28th, to June 5th,

240 × 4260 cc. = 1.022400 cc. gave of platinum precipitate,

0.00645 gr.

The precipitate from the water and reagents amounted to 0.0007 gr., which, deducted from the above, gives 0.00575, which, for 100 jars = 0.00239 gr.

The next and last determination was made on the summit of Prospect Hill, in the neighborhood of Cambridge, distant from dwellings and habitations of every kind, and about 150 feet above tide level.

5th Determination, June 18th and 20th, 180 × 4260 cc. of air gave of platinum precipitate

0.00705 gr.

The water and reagents gave 0.00140 gr., which, deducted from the above, leaves 0.00565 gr., which, calculated for 100 × 4260, gives 0.00314 gr.

These results placed together are as follows : —

426,000 cc. of air gave

| | | $PtCl_2\ NH_4Cl$ | $= NH_3$ | = in 1,000,000 cc. tr. |
|---|---|---|---|---|
| April 25th, | 1. 2. | 0.00365 gr. | 0.000278 gr. | 0.0006158 gr. |
| May 1st, | 3. 4. | 0.00272 " | 0.000207 " | 0.0004592 " |
| May 18th, | 5. 6. | 0.00650 " | 0.000495 " | 0.0011619 " |
| May 28th, | 7. | 0.00239 " | 0.000182 " | 0.0004037 " |
| June 18, 20, | 8. | 0.00314 " | 0.000240 " | 0.0005633 " |
| | | | Average = | 0.0006407 " |

This is about one half-millionth of the average weight of the air. This average is very nearly coincident with the result of the last series of observations by J. Pierre,* which were continued through nine months with 4075 litres of air. One cubic metre of air contained 0.00065 gr.

His first series,† which he afterward discovered to be faulty, gave for one cubic metre 0.0045 gr., or about three and a half millionths of the weight of the air.

Fresenius ‡ found in the atmosphere of daylight for forty days in August and September, 1848, for one million parts of air by weight, only 0.098 parts, and for night air for the same weight, 0.169 parts.

Kemp § found for the same 3.40, and Grager ‖ 0.333. Ville ¶ made sixteen determinations in 1849–1850, employing from 20,000 to 55,000 litres of air. His range was from 17.76 gr. to 31.71 gr., averaging 23.73 gr. for one million kilogrammes of air.

A second series by the same observer in 1850 (1851?) gave for the same weight of air from 16.52 gr. to 27.26 gr., average 21.10 gr. For the average of the two, 22.41 gr., or in one million parts by weight, 0.02241 parts of ammonia.

Bineau ** estimates the air about Lyons to contain from one fourth to one fifth of one millionth of its weight of ammonia. That of Caluire to contain in winter forty billionths, in summer eighty billionths.

Bineau's †† observations are based upon the supposition that the ammonia and carbonic acid of the air are in equivalent proportions, and that both were alike absorbed by his method.

He obtained by his method for Lyons, in 1,000,000,000 parts, from

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* Liebig and Kopps, Jahresbericht, 1853, p. 333.

† Liebig and Kopps, Jahresbericht, 1852, p. 356.

‡ Liebig and Kopps, Jahresbericht, 1849, p. 258.

§ Pharm. Centr. Blatt, 1848, p. 315.

‖ Liebig and Kopps, Jahresbericht, 1849, p. 258.

¶ Liebig and Kopps, Jahresbericht, 1852, p. 356.

** Liebig and Kopps, Jahresbericht, 1854, p. 315.

†† My own determinations in 1849 were so exceedingly erroneous as not to be entitled to record, but may show how wide a departure from a true result may be possible where a method is defective. One million parts by weight gave from 1.2 to 47.6 parts of ammonia, the average of which is nearly fifty times as great as was found to be present.

200 to 250 parts of ammonia, and at Caluire, in winter 40, and in summer 80 parts.

Placing these results in form for comparison, they give in one million cubic metres, according to

| | | | |
|---|---|---|---|
| Grager, | | | 432.00 gr. |
| Kemp, | | | 4423.00 " |
| Fresenius, | day, | | 127.27 " |
| | night, | | 219.47 " |
| Ville, 1st series, | | | 30.81 " |
| " 2d series, | | | 27.39 " |
| Bineau, | Lyons average, | | 292.50 " |
| | Caluire, | winter, | 52.00 " |
| | | summer, | 104.00 " |
| J. Pierre, 1st series, (erroneous,) | | | 4500.00 " |
| " 2d series, | | | 650.00 " |
| Horsford, | | | 640.70 " |

This near coincidence of the last two results, taken in connection with the time consumed in producing the first, and the number and differential character of the determinations giving the second, entitles them, possibly, to a higher degree of confidence than any of the preceding results.

Taking the round number, 645, as the number of grammes in one million cubic metres of air, or 1,298,701 kilogrammes of air, and taking, according to Marchand, the weight of the atmosphere at 5,263,623,000,000,000,000 kilogrammes, and assuming it to be of uniform constitution, we have in the total atmosphere 2,614,178,964,211 kilogrammes of ammonia.* Or, expressed in English weights, 11,613,808,176,000,000,000,000 pounds of atmospheric air contain 5,767,999,157,462 pounds of ammonia.

* In Fresenius's estimates, as published in Erdmann and Marchand's Journal f. Prakt. Chemie, Vol. XLVI. pp. 101-106, I find two errors that have escaped the author's eye. He gives Kemp's quantity of ammonia in 1,000,000 parts of air by weight at 3.68. It should be 3.40. He finds the number of kilogrammes of ammonia in the air, upon the average of 0.133 parts in 1,000,000 by weight (his own determination), and Marchand's estimate as given above, to be 4,079,042 kilogrammes. It should be 700,061,859,000 kilogrammes.

## IV. PHYSICS OF THE GLOBE.

### 1. Approximate Cotidal Lines of Diurnal and Semi-Diurnal Tides of the Coast of the United States on the Gulf of Mexico. By A. D. Bache, Superintendent U. S. Coast Survey. [Communicated by Authority of the Treasury Department.]

At successive meetings of the American Association I have presented approximate cotidal lines for the Atlantic and Pacific coasts of the United States, drawn from the tidal observations of the Coast Survey. I now present similar lines for our coast on the Gulf of Mexico.

The problem is a very different one from either of the others referred to. The tides on the Atlantic coast are of the regular semi-diurnal class, and easily discussed by the forms already elaborately prepared by Lubbock and Whewell. The diurnal inequality is not large; indeed, though easily recognized at particular periods, and then quite characteristic, in general it is difficult to trace, and often irregular in magnitude, and even in sign. Those of the Pacific coast are remarkably regular in the semi-diurnal and diurnal waves, and both rise to such heights as to make observation easy. On the Gulf coast, on the contrary, the tides are small, and therefore easily affected by extraneous circumstances, and, as a rule, on more than two thirds of the coast the semi-diurnal tides are very small, and in fact are masked by the diurnal tide. The comparatively imperfect discussion which has been made of these tides requires many steps in the discussion to be supplied, and sometimes leaves us in doubt as to the exact interpretation of the results.

By way of preparing for the present discussion, and to avoid running into too great length at this time, I gave at the last meeting of the Association an account of the tidal observations made on our Gulf coast, and showed the type curves for the different stations from Cape Florida to the Rio Grande.* I also explained the method of decomposition of the curves of observation into diurnal and semi-diurnal waves, and gave the analysis of the type curves at the several tidal stations. From Cape Florida, along the Keys, and up the western coast of the

* Proceedings of the American Association for the Advancement of Science, Providence Meeting, 1855, p. 152.

peninsula, to St. George's, the tides are of the half-day class, with a large diurnal inequality; from St. George's, which belongs to the day class, to Southwest Pass, they are of the day type, the semi-diurnal tide almost disappearing; at Dernière Island, Calcasieu, and Galveston they resume as a rule the half-day type, and lose it almost completely at Aransas and the mouth of the Rio Grande. Isle Dernière, and less distinctly Calcasieu, show cases of interference in the semi-diurnal wave, two high waters being at times easily traced in the semi-diurnal curve.

The character of the tidal phenomena themselves, the peculiarities in configuration and in depth of the basin, the limited extent over which our researches spread, and various other circumstances, contribute to render this work less satisfactory than the former. Some of these will, in the end, disappear, as the Gulf is more fully explored in the progress of the survey. Our information thus far extends to but one entrance of the basin, that by the Gulf of Florida, and of this to but one shore, while of the nature of the tide wave which enters from the Caribbean Sea, through the straits between the western end of Cuba and the eastern end of Yucatan, we have no reliable information. Some of these causes render present speculation premature, and lie at the very threshold of attempts to trace out the great interference problems which present themselves.

The progress of this discussion has also shown that observations of longer period are necessary in many cases to give data for conclusive results. This of itself is a great point gained, and the practical results for the charts of this coast have repaid all the labor which has been expended on the observations. Navigators were absolutely without information other than the most vague in regard to the tides of the Gulf.

The hourly observations at each station being plotted in diagrams upon a suitable scale, the curves of observation were decomposed, by the graphical method introduced by Mr. Pourtales, into a diurnal and semi-diurnal curve. It may be proper to observe here, that several comparisons have been made between this method and that which I had formerly used by the sine curves, and with generally coincident results. The graphical method, besides being less laborious, is free from the hypothesis of the sine curve. These decompositions were made chiefly by Messrs. Fendall and Heaton of the tidal party, and occasionally by Professor Pendleton and Mr. S. Walker.

That the diurnal wave is the principal feature in these tides, will appear from the annexed table, which gives the names and positions

TABLE I.

| Stations. | Height of Semi-diurnal Tides. | Height of Diurnal Tides. | Height of Observed Tides. |
|---|---|---|---|
| | ft. | ft. | ft. |
| Cape Florida, | 1.6 | 0.2 | 1.5 |
| Indian Key, | 1.9 | 0.6 | 1.8 |
| Key West, | 1.2 | 0.7 | 1.4 |
| Tortugas, | 1 0 | 1.0 | 1.2 |
| Egmont Keys, | 1.1 | 1.6 | 1.4 |
| Cedar Keys, | 2.4 | 1.5 | 2.5 |
| St. Mark's, | 2.2 | 1.8 | 2.2 |
| St. George's Island, | 0.2 | 1.6 | 1.1 |
| Pensacola, | 0.2 | 1.1 | 1.0 |
| Fort Morgan (Mobile Bay), | 0.2 | 1.1 | 1.0 |
| Cat Island, | 0.3 | 1.2 | 1.3 |
| Southwest Pass, | 0.2 | 1.2 | 1.1 |
| Dernière Isle, | 0.4 | 1.6 | 1.4 |
| Calcasieu, | 1.3 | 1.5 | 1.1 |
| Galveston, | 0.5 | 1.1 | 1.1 |
| Aransas, | 0.5 | 1.3 | 1.1 |
| Brazos Santiago, | 0.3 | 0.8 | 0.9 |

TABLE II.

*Tide Tables in the Gulf of Mexico, the Results of which are Discussed in this Paper.*

| No. | Stations. | Date of Observation. | Kind of Gauge. | Observers. |
|---|---|---|---|---|
| 1 | Cape Florida, Fla. | April 22 to Oct. 31, 1854, | S.R.* | L. E. Tansill. |
| 2 | Indian Key, " | Jan. 21 to April 16, 1855, | S.R. | L. E. Tansill. |
| 3 | Key West, " | Apr. 20, 1850, to Dec. 31, '51, | Box, | W. Lane & G. W. Goss. |
| 4 | Tortugas, " | April 1 to June 22, 1855, | S.R. | C. T. Thompson and F. Buxton. |
| 5 | Egmont Key, " | April 22 to Aug. 23, 1854, | " | C. T. Thompson. |
| 6 | Cedar Keys, " | Jan. 10 to Mar. 16, 1852, | Box, | G. Wurdemann. |
| 7 | St. Mark's, " | Nov. 3, 1854, to Mar. 2, '55, | S.R. | C. T. Thompson. |
| 8 | St. George's Isl., " | April 11 to Aug. 16, 1852, | Box, | G. Wurdemann. |
| 9 | Pensacola, " | Aug. 27 to Oct. 31, 1852, | " | G. Wurdemann. |
| 10 | Fort Morgan, Ala. | Aug. 20, 1850, to May 26, '51, | " | G. Wurdemann. |
| 11 | Cat Island, La. | Dec. 29, 1847, to Feb. 13, '49, | " | G. Wurdemann and R. T. Bassett. |
| 12 | Southwest Pass, " | Nov. 19, 1852, to Mar. 28, '53, | " | G. Wurdemann. |
| 13 | Dernière Isl., " | April 5 to June 12, 1853, | " | G. Wurdemann. |
| 14 | Calcasieu, " | Feb. 24 to May 26, 1854, | S.R. | G. Wurdemann. |
| 15 | Bolivar Pt., Tex. | Oct. 1, 1853, to June 1, 1854, | " | L. E. Tansill. |
| 16 | Galveston, " | Mar. 21, 1851, to Jan. 1, 1853, | Staff, | G. Price and F. Muhr. |
| 17 | Aransas Pass, " | Nov. 1, 1853, to Jan. 31, 1854, | Box, | G. Wurdemann. |
| 18 | Brazos Sant., " | July 7 to Oct. 13, 1853, | " | G. Wurdemann. |

* Self-registering tide-gauge.

of the tidal stations, the average rise and fall of the tide at each, and the height of the diurnal and semi-diurnal waves composing the observed tide. Table No. II. shows the periods during which the tidal observations were made, and the names of the observers.

A diagram (No. 1) shows these results graphically. A curved line corresponding to the general outline of the shore, cutting off its irregularities, is drawn on the chart of the Gulf coast, and then developed into a straight line. Thus the tidal stations are plotted at their distances from each other measured along the general line of the coast. For use by navigators, any intermediate stations may be marked in, in the same way, and a rough approximation to the character of the tide be obtained by the interpolation.

The least observed height is 0.9 foot, at Brazos Santiago, and the greatest 2.5 feet, at Cedar Keys. The least height of the average semi-diurnal tide is 0.2 foot, at Southwest Pass, and the greatest 2.4 feet, at Cedar Keys. The least height of the average diurnal tide is 0.2 foot, at Cape Florida, and the greatest 1.8 feet, at St. Mark's. Of course, these numbers are, for reasons easily seen, only approximations.

As we enter the Gulf of Mexico by the Straits of Florida, the height of the tide first increases, then decreases. Passing into the bight at the upper end of the Florida peninsula, the rise is greatest; west of St. George's it diminishes, to rise again in the bight formed by the southern coast of Louisiana and the eastern coast of Texas.

In the decompositions here traced, and in the very laborious discussions, tentative and final, of the whole of the observations upon which this paper is based, I would acknowledge the great assistance derived from the labors of Assistant L. F. Pourtales, in charge of the tidal division of the Coast Survey. The unwearied assiduity of his own labors, and his intelligent supervision of the work of others, have been felt at every step in the progress of these investigations. They have required, on his part, great resources of ingenuity, patience, and knowledge.

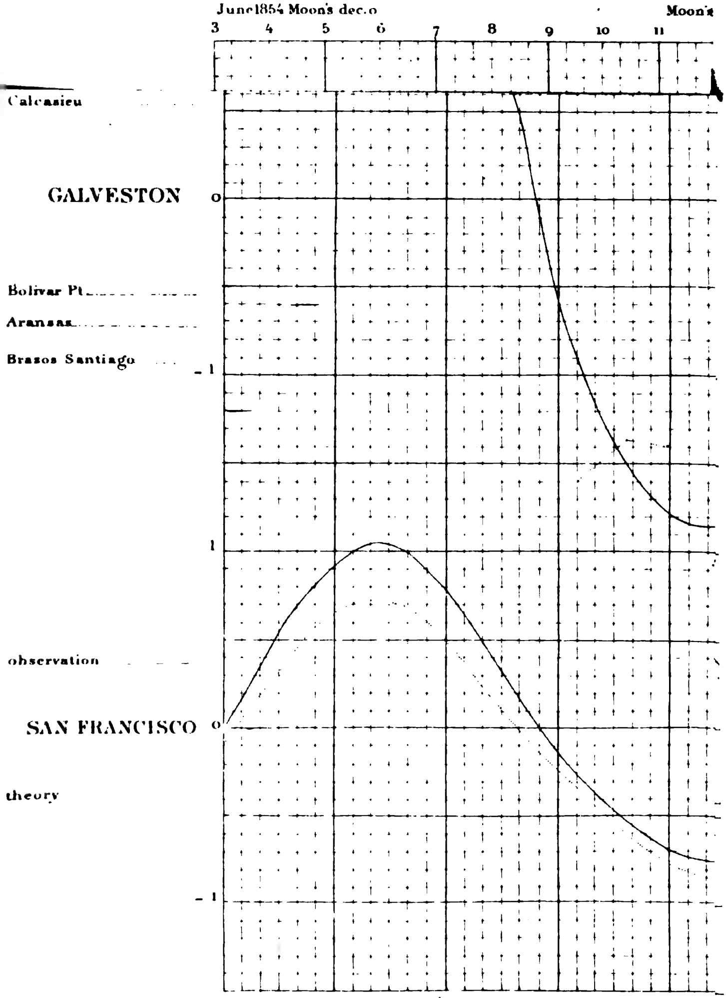
In discussing semi-diurnal tides, the luni-tidal interval of high or low water, varying only from a certain mean within moderate limits, affords a cardinal datum (the establishment) for the times. In the diurnal tides this datum is wanting.

The law of the change of the diurnal tide, as expressed in the formula of Professor Airy (Tides and Waves, Encyclopædia Metropoli-

DIAG

Showing the variations in the lunitidal

to Moon's declination at Egm



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tana, p. 254, Art. 46), is in general represented; but the great flatness in the form of the curves at particular relations of the moon's right ascension and declination, required by the formula, does not occur. The general form of these curves is shown upon the diagram No. 2, where the abscissæ represent the days, and the ordinates the luni-tidal intervals of high water. About the maximum of declination, for some four to six days, the luni-tidal intervals are moderately constant, and the average of these is what I have taken for a comparison of the luni-tidal intervals to trace the progress of the diurnal wave. The variations from day to day being less than the probable irregularities in the times of high water and the uncertainties in the observations, these means give suitable numbers for comparison. The result would not have been greatly different had only a few of the observations at either end of the declination period been thrown off; but after examination we found these numbers to present apparently the best results.

At four of the stations, namely, Key West, Fort Morgan, Cat Island, and Galveston, hourly observations were continued during a year and upwards, and the decompositions in all the cases but Cat Island embrace that period. The annual change of diurnal establishment (using this term as a convenient one in the sense heretofore stated) is very clearly seen in all these cases, and is shown in diagram No. 3. The law of the change is beautifully developed in the larger tides of the Western coast, and, as deduced from the San Francisco observations, is shown upon the same diagram. In all the cases the actual computed results for the different half-monthly periods are shown by the broken lines on the diagrams, and the curve, representing the law, is drawn with a free hand among the points. The general resemblance of these curves, with however different maximum ordinates, is very striking, showing that the law of the change is the same, only the coefficients of the functions varying.

On diagram No. 4 the curve derived from Professor Airy's formula (Theory of Tides and Waves, Encyclopædia Metropolitana, p. 254, Art. 46) is drawn, as well as that from observation for San Francisco, and the general conformity is quite striking. In making use of the curves as expressing the law of annual change, one of the branches has been turned over upon the other, so as to use the mean of the two periods of six months.

At the other fourteen stations on the Gulf of Mexico, the observations were continued from one to three lunations, and fell in different parts of the year. To reduce these, therefore, to the same period of the year, it is necessary to employ the data from the localities where the whole annual change was embraced. The results are plotted on diagram No. 4; those from the Brazos to Southwest Pass on the curve for Galveston, those from the Southwest Pass to St. George's on the curve for Fort Morgan, and those from St. George's to Cape Florida on the curve for Key West. There is, except in one case, a general conformity in the observed changes, and in those deduced from the other comparisons; at least, there are no greater contradictions than those presented by the observations from which the mean curves are drawn. From these plottings, the correction necessary to reduce the results to the mean of the year are derived, and the annexed table shows the diurnal interval as deduced directly from the observations and as corrected. It is satisfactory to see that the correction makes the results more conformable to law, increasing therefore the probability that the correction is rightly applied, and is approximately correct in magnitude.

TABLE III.

| No. | Stations. | Latitude. | Longitude. | Longitude in Time. | Mean Diurnal Luni-tidal Interval near Maximum of Moon's Declin. | Longitude + Establishment. | Correction for Transit. | Correction for Depth. | Correction for Yearly Variation of Diurnal Luni-tidal Interval. | Corrected Cotidal Hour. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | h. m. | h. m. | h. m. | h. m. | h. m. | h. m | h. m. |
| 1 | Cape Florida, | 25 40 | 80 9 | 5 21 | 14 27 | 19 48 | 0 27 | 0 20 | + 0 18 | 19 19 |
| 2 | Indian Key, | 24 52 | 80 44 | 5 23 | 17 0 | 22 23 | 34 | 20 | — 42 | 20 47 |
| 3 | Key West, | 24 27 | 81 53 | 5 28 | 18 32 | 24 0 | 37 | 19 | 0 | 23 4 |
| 4 | Tortugas, | 24 34 | 82 59 | 5 32 | 18 5 | 23 37 | 36 | 10 | + 43 | 23 34 |
| 5 | Egmont Key, | 27 36 | 82 46 | 5 31 | 19 19 | 24 50 | 39 | 20 | + 1 | 23 52 |
| 6 | Cedar Keys, | 28 58 | 82 57 | 5 32 | 22 27 | 27 59 | 43 | 45 | — 57 | 25 34 |
| 7 | St. Mark's, | 30 0 | 84 11 | 5 37 | 21 56 | 27 33 | 42 | 22 | + 20 | 26 49 |
| 8 | St. George's Island, | 29 35 | 85 12 | 5 41 | 19 41 | 25 22 | 42 | 25 | + 37 | 24 52 |
| 9 | Pensacola, | 30 18 | 87 15 | 5 49 | 21 28 | 27 17 | 42 | 17 | + 22 | 26 40 |
| 10 | Fort Morgan, | 30 9 | 88 0 | 5 52 | 21 21 | 27 13 | 42 | 14 | 0 | 26 14 |
| 11 | Cat Island, | 30 6 | 88 38 | 5 55 | 22 21 | 28 16 | 43 | 1 21 | — 11 | 26 1 |
| 12 | Southwest Pass, | 28 56 | 89 22 | 5 57 | 19 28 | 25 25 | 39 | 21 | + 59 | 25 24 |
| 13 | Dernière Island, | 28 58 | 90 58 | 6 4 | 19 19 | 25 23 | 38 | 24 | + 1 37 | 25 58 |
| 14 | Calcasieu, | 29 40 | 93 21 | 6 13 | 19 22 | 25 35 | 39 | 17 | + 1 27 | 26 6 |
| 15 | Bolivar Point, | 29 23 | 94 46 | 6 19 | 21 40 | 27 59 | 43 | 12 | + 1 24 | 28 28 |
| 16 | Galveston, | 29 18 | 94 41 | 6 19 | 22 29 | 28 48 | 43 | 30 | 0 | 27 35 |
| 17 | Aransas Pass, | 28 15 | 96 31 | 6 26 | 19 46 | 26 12 | 40 | 17 | + 0 43 | 26 0 |
| 18 | Brazos Santiago, | 26 6 | 97 10 | 6 29 | 20 45 | 27 14 | 41 | 15 | — 0 56 | 25 22 |

…ne first column of the table contains a number for reference; the …nd, the name of the tidal station; the third, fourth, and fifth, the …ude and longitude, the latter in degrees and in time; the sixth, the …-tidal interval about the maximum of declination; the seventh, the …n of this last-named number and the longitude in time; the eighth, … correction to reduce the observations to the same transit; the ninth, … correction for depth, carrying these by the law of depth to deep …ter; the tenth, the correction to reduce the observed luni-tidal inter…l at maximum to the mean of the year; the eleventh, the corrected …tidal hour.

The table enables us satisfactorily to trace the diurnal wave from …ape Florida to the Tortugas, across by the deep water of the Gulf … Southwest Pass, at the entrance of the Mississippi, and from this …ine of deep water to the western coast of the peninsula of Florida, …y Egmont Key (Tampa), Cedar Keys, St. Mark's, and St. George's Island, and in the bay between Southwest Pass and St. George's, by Cat Island, Fort Morgan, and Pensacola. Again, in the bight between Southwest Pass and the Rio Grande, to the Rio Grande, Isle Dernière, Aransas, and Calcasieu, up to Galveston.

In obtaining the general direction of the cotidal lines, I have followed the method of grouping used in my former papers in the forms given by Professor Lloyd. It is easy to obtain an idea of the movement of the diurnal wave in this way, but the selection of the groups required a tedious set of trials, and the discussion of many groups which appeared natural proved very unsatisfactory. The burden of the computations for this work has fallen upon Mr. John Downes.

Table No. IV. shows the groups selected, with a letter attached for reference, the names of the stations constituting the groups, the mean latitude and longitude and cotidal hour of the group, the values of the coefficients of each, the angle of the cotidal line with the meridian, the difference of the cotidal hour for one mile perpendicular to the movement of the wave, and the velocity in miles per hour.

On the character of these groups I would remark as follows: — Group A, Cape Florida, Indian Key, and Key West, and B, Indian Key, Key West, and Tortugas, give a natural movement for the wave, though showing a more abrupt change than is probably real. The computed and observed cotidal hours differ, at the greatest, but one minute and a quarter. The next group, C, gives a satisfactory idea

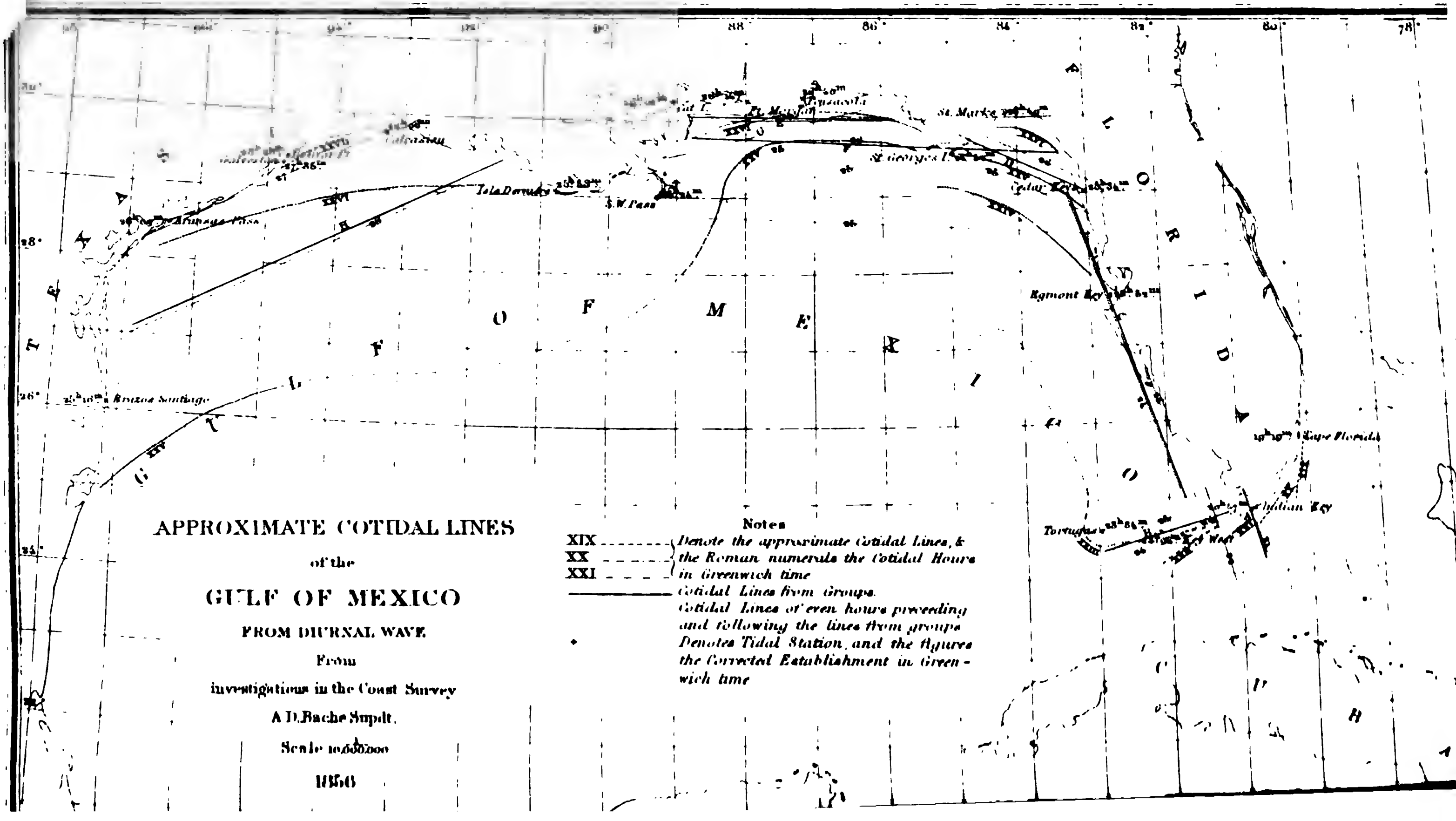
## TABLE IV.

*Discussion of Groups of Tidal Stations for Diurnal Wave.*

| | Stations. | Mean Longitude. | Mean Latitude. | Mean Cotidal Hour. | $M$ Diff. of Cotidal Hour for one Geog. Mile of Longitude. | $N$ Diff. of Cotidal Hour for one Geog. Mile of Latitude. | Angle $\left[\tan g = \frac{N}{M}\right]$ Cotidal Angle. | $\sqrt{M^2+N^2}$ Diff. of Cotidal Hour correspond'g to one Geographical Mile Perpendicular to Cotidal Line. | Miles per Hour of Tidal Wave. |
|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | h. m. | | | ° ′ | | |
| A | Cape Florida, Indian Key, Key West, | 80 55 | 25 0 | 21 3 | —1.978 | —0.509 | —14 28 | 2.052 | 29.2 |
| B | Indian Key, Key West, Tortugas, | 81 52 | 24 38 | 22 28 | —0.890 | —3.240 | 74 38 | 3.360 | 17.8 |
| C | Key West, Egmont Key, Cedar Keys, | 82 32 | 27 0 | 24 10 | 5.251 | 1.695 | —17 53 | 5.518 | 10.9 |
| D | Cedar Keys, St. Mark's, St. George's Island, . . . . | 84 7 | 29 31 | 25 45 | 1.095 | 2.358 | —65 5 | 2.600 | 22.7 |
| E | St. George's Island, Pensacola, Fort Morgan, . . . | 86 49 | 30 1 | 25 55 | 0.055 | 2.645 | —88 49 | 2.645 | 22.7 |
| F | Cedar Keys, St. Mark's, St. George's Isl., Pensacola, Fort Morgan, Cat Isl., S. W. Pass, . . | 86 31 | 29 43 | 25 56 | 0.048 | 0.911 | —86 58 | 0.910 | 66.0 |
| G | St. George's Island, Pensacola, Ft. Morgan, Cat Island, S. W. Pass, . . | 87 41 | 29 49 | 25 50 | —0.275 | 1.092 | 75 52 | 1.127 | 53.1 |
| H | S.W. Pass, Dernière Isl., Calcasieu, Galveston, Aransas, Brazos, . . . | 93 45 | 28 28 | 26 4 | —0.241 | 0.944 | 63 19 | 0.974 | 61.6 |

of the movement of the wave passing round the Tortugas and up along the coast of the peninsula, over the extensive flat which borders it. The next group, D, Cedar Keys, St. Mark's, and St. George's, presents a perfect agreement between the computed and observed cotidal hours, and a direction and velocity agreeing with what might have been supposed. The same is true for group E, St. George's, Pensacola, and Fort Morgan. The more general group, F, including the stations from Cedar Keys to Southwest Pass, agrees in its indica-

DIAGRAM V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APPROXIMATE COTIDAL LINES
of the
GULF OF MEXICO
FROM DIURNAL WAVE
From
investigations in the Coast Survey
A D. Bache Supdt.
Scale 1/10,000,000
1856
Notes
XIX ------ } Denote the approximate Cotidal Lines, &
XX - - - - } the Roman numerals the Cotidal Hours
XXI - - - } in Greenwich time
Cotidal Lines from Groups.
Cotidal Lines of even hours preceding and following the lines from groups
Denotes Tidal Station, and the figures the Corrected Establishment in Greenwich time
T E X A S
G U L F   O F   M E X I C O
F L O R I D A
Isla Dernier
S.W. Pass
Pensacola
St. Marks
St. George's I.
Cedar Keys
Egmont Key
Cape Florida
Indian Key
Key West
Tortugas
Brazos Santiago
Aransas Pass
Galveston
Calcasieu
88°
86°
84°
82°
80°
78°
28°
26°
24°

tions with those given by the partial groups; as does also G, including the stations from St. George's to Southwest Pass. In passing westward and southward, the direction of the line changes rapidly, and no satisfactory adjustment by groups could here be made. From Southwest Pass to the Brazos Santiago, the smaller groups gave decidedly anomalous results for adjacent stations, pointing to the more general arrangement of the lines shown by group H, composed of Southwest Pass, Dernière Isle, Calcasieu, Galveston, Aransas, and Brazos Santiago. The agreement of the cotidal hours, as computed and observed, is only tolerable. The results of the computations for Southwest Pass, Dernière Isle, and Aransas differ severally but 10, 1, and 9 minutes from the observed, but those for Calcasieu, Galveston, and Brazos differ 60, 33, and 44 minutes.

On the map No. V. a rough outline of the Gulf coast is traced, and the cotidal hours are marked near the stations. The mean cotidal line for each group, and the hour before and after the mean hour, are marked on the map, showing the direction and velocity of the diurnal wave as given by the groups. From a consideration of these, and of their necessary connection, the cotidal lines are approximately drawn. The main cotidal line of the northern shore of the Gulf, as traced upon the chart, is that of twenty-six hours; twenty-seven occurring at the head of the bight in which Galveston lies. The twenty-five hour line appears at Cedar Keys and touches the coast again below Brazos, twenty-three is at the Tortugas and Key West, and nineteen at Cape Florida.

## Semi-Diurnal Tides.

The Table No. V. of semi-diurnal tides is in the same form as No. III. for diurnal tides. It contains a number for reference, the name of the station, its latitude, the longitude in arc and in time, the establishment, the same in Greenwich time, the correction for transit and for depth, and the corrected cotidal hour.

In tracing the semi-diurnal wave as it enters the Straits of Florida, we find, after a slight contradiction between Cape Florida and Indian Key, a general increase of the cotidal wave in the right direction to the Tortugas. The semi-diurnal wave here gives the difference of time between Cape Florida and the Tortugas of but $1^{h.}\ 24^{m.}$, while the diurnal wave gives $4^{h.}\ 15^{m.}$. The lagging of the diurnal wave, which

at Cape Florida is $1^{h.}$ $44^{m.}$, at Indian Key is $3^{h.}$ $22^{m.}$, at Key West $4^{h.}$ $31^{m.}$, and at the Tortugas $4^{h.}$ $23^{m.}$.

The semi-diurnal wave passes across the Gulf to the Southwest Pass as did the diurnal, the establishment at the Tortugas being $14^{h.}$ $25^{m.}$, and at the Southwest Pass $15^{h.}$ $38^{m.}$. The time of crossing by the semi-diurnal wave is, however, $1^{h.}$ $13^{m.}$, while by the diurnal wave it was $1^{h.}$ $50^{m.}$. The lagging of the diurnal wave behind the semi-diurnal, which at the Tortugas was $9^{h.}$ $26^{m.}$, at the Southwest Pass is $4^{h.}$ $49^{m.}$. The mean depth of the portion of the Gulf traversed by the wave computed from the semi-diurnal wave is sixteen hundred and sixty-six fathoms, and from the diurnal six hundred and sixty-six fathoms; for the mean result of the two, one thousand fathoms. The average depth has not yet been ascertained, but probably does not exceed one thousand fathoms.

TABLE V.

*Half-Daily Cotidal Hours in the Gulf of Mexico.*

| No. | Names of Stations. | Latitude. | Longitude In Arc. | Longitude In Time. | Establishment of Half-daily Tides. | Establishment Greenwich Mean Time. | Correction For Transit. | Correction For Depth. | Corrected Cotidal Hour. |
|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | h. m. | h. m. | h. m. | m. | m. | h. m. |
| 1 | Cape Florida, | 25 40 | 80 9 | 5 21 | 8 17 | 13 38 | — 17 | — 20 | 13 1 |
| 2 | Indian Key, | 24 52 | 80 44 | 5 23 | 8 2 | 13 25 | — 16 | — 15 | 12 54 |
| 3 | Key West, | 24 27 | 81 53 | 5 28 | 9 10 | 14 38 | — 18 | — 19 | 14 1 |
| 4 | Tortugas, | 24 34 | 82 59 | 5 32 | 9 22 | 14 54 | — 19 | — 10 | 14 25 |
| 5 | Egmont Key, | 27 36 | 82 46 | 5 31 | 11 26 | 16 57 | — 23 | — 20 | 16 14 |
| 6 | Cedar Keys, | 28 58 | 82 57 | 5 32 | 13 9 | 18 41 | — 26 | — 45 | 17 30 |
| 7 | St. Mark's, | 30 0 | 84 11 | 5 37 | 13 37 | 19 14 | — 27 | — 22 | 18 25 |
| 8 | St. George's Island, | 29 35 | 85 12 | 5 41 | 14 59 | 20 40 | — 30 | — 25 | 19 45 |
| 9 | Pensacola, | 30 18 | 87 15 | 5 49 | 10 53 | 16 42 | — 22 | — 17 | 16 3 |
| 10 | Fort Morgan, | 30 9 | 88 0 | 5 52 | 11 9 | 17 1 | — 22 | — 14 | 16 25 |
| 11 | Cat Island, | 30 6 | 88 38 | 5 55 | 12 53 | 18 48 | — 26 | — 81 | 17 1 |
| 12 | Southwest Pass, | 28 56 | 89 22 | 5 57 | 10 23 | 16 20 | — 21 | — 21 | 15 38 |
| 13 | Dernière Island, | 28 58 | 90 58 | 6 4 | 13 37 | 19 41 | — 27 | — 24 | 18 50 |
| 14 | Calcasieu, | 29 40 | 93 21 | 6 13 | 14 56 | 21 9 | — 30 | — 17 | 20 22 |
| 15 | Bolivar Point, | 29 23 | 94 46 | 6 19 | 16 47 | 23 6 | — 34 | — 12 | 22 20 |
| 16 | Galveston, | 29 18 | 94 41 | 6 19 | | | | — 30 | |
| 17 | Aransas Pass, | 28 15 | 96 31 | 6 26 | 14 30 | 20 56 | — 29 | — 17 | 19 10 |
| 18 | Brazos Santiago, | 26 6 | 97 10 | 6 29 | 14 45 | 21 14 | — 29 | — 15 | 20 30 |

From this line of deep water the semi-diurnal wave reaches the stations on the western coast of the Florida peninsula in their order, from south to north, and west. The movement west of St. George's appears to be in the order of Pensacola, Fort Morgan, and Cat Island, while for the diurnal wave it was Cat Island, Fort Morgan, and Pensa-

cola. To the westward of Southwest Pass there is a sudden increase of establishment, as if another semi-diurnal wave brought the tides there. The mean cotidal hour of the five stations west of Southwest Pass is $20^{h.}\ 14^{m.}$, while that of Southwest Pass and three east of it is $16^{h.}\ 17^{m.}$, a difference of about four hours. This, taken with the remarks already made in regard to the appearance of two high waters in the curves for Isle Dernière and Calcasieu, indicates a system of interferences yet to be unravelled.

As was the case with the diurnal wave, the stations at Isle Dernière and Calcasieu gave cotidal hours very like those of Brazos Santiago and Aransas, and Galveston is later than either.

Upon the whole, then, there is a general resemblance in the motion of the two waves as assigned by observation, with some considerable discrepancies. The annexed Table No. VI. shows the difference between the establishments of the diurnal and semi-diurnal waves at the several stations.

TABLE VI.

*Comparison of Establishments of Half-Day and Day Tides, in the Gulf of Mexico.*

| No. | Stations. | Difference between Day and Half-Day. |
|---|---|---|
| | | h. m. |
| 1 | Cape Florida, | 6 28 |
| 2 | Indian Key, | 8 16 |
| 3 | Key West, | 9 22 |
| 4 | Tortugas, | 9 26 |
| 5 | Egmont Key, | 7 54 |
| 6 | Cedar Key, | 8 21 |
| 7 | St. Mark's, | 8 39 |
| 8 | St. George's Island, | 5 19 |
| 9 | Pensacola, | 10 57 |
| 10 | Fort Morgan, | 10 12 |
| 11 | Cat Island, | 9 17 |
| 12 | Southwest Pass, | 10 4 |
| 13 | Dernière Island, | 7 19 |
| 14 | Calcasieu, | 5 53 |
| 15 | Bolivar Point, | 6 17 |
| 16 | Aransas Pass, | 5 59 |
| 17 | Brazos Santiago, | 5 4 |

When we come to follow these results into the discussion of the groups, they are far from satisfactory. Perhaps this was to have been expected from the circumstances before stated. The groups were nevertheless elaborately examined, though without much fruit. The table of groups is arranged as for the diurnal tides, containing, as before, a number for reference, the names of the stations, and the lati-

tude and longitude, the values of the coefficients of each, the angle made by the cotidal line with the meridian, the movement of the wave perpendicular to the cotidal line expressed by the number of minutes employed in traversing a mile, and the miles per hour. See Table VII.

## TABLE VII.

*Recapitulation of Groups for Half-Day Tides.*

| | Stations in Group. | Mean Longitude. | Mean Latitude. | Mean Cotidal Hour. | $M$ | $N$ | Angle. | Minutes to one Mile. | Miles per Hour. |
|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | h. m. | | | ° ′ | | |
| A | Cape Flor., Ind. K., K. West, | 80 55 | 25 0 | 13 19 | -1.515 | 1.151 | 37 14 | 1.902 | 31.5 |
| B | Ind. K., Key West, Tortugas, | 81 52 | 24 38 | 13 47 | -0.551 | -1.288 | -66 49 | 1.401 | 42.8 |
| C | Egm. K., Cedar K., St. Mark's, | 83 18 | 28 51 | 17 23 | 0.049 | 0.935 | -87 0 | 0.935 | 64.2 |
| D | Ft. Mor., Cat Isl., S. W. Pass, | 88 40 | 29 44 | 16 21 | -1.260 | 1.887 | 56 16 | 2.269 | 26.4 |
| E | Isle Dern., Calcas., Bolivar Pt., | 93 2 | 29 20 | 20 31 | -1.246 | -1.517 | 50 36 | 1.963 | 30.6 |
| F | S. W. Pass, Dern. Isl., Calcasieu, Bolivar Pt., Brazos, | 93 7 | 28 37 | 19 32 | -1.243 | 1.488 | 50 07 | 1.939 | 30.9 |

Groups A and B, composed of Cape Florida, Indian Key, and Key West, and of Indian Key, Key West, and Tortugas, give, especially the first, plausible results, and the computed establishments vary but $1^{m}.5$, at the greatest, from the observed. I have not been able to form any satisfactory connection between these groups and those on the western coast of the peninsula. The next group, which gives a tolerable result, is Egmont Key, Cedar Keys, and St. Mark's. In this the direction of the cotidal line, the velocity, and the establishments are satisfactory.

The establishment of St. George's station is irregular, and is very probably erroneous. The semi-diurnal wave is composed of two very small ones, and it has been necessary to reconcile the discrepancies which they presented, sometimes one being the governing tide, and sometimes the other.

Group D, composed of Fort Morgan, Cat Island, and Southwest Pass, is the next, which gives a good result.

E, composed of Isle Dernière, Calcasieu, and Bolivar Point, and F, of all the stations from Southwest Pass to Brazos Santiago except Aransas, give good results as to direction and velocity, the cotidal hour of twenty for the two groups falling upon each other. The computed establishments, as in the case of the diurnal wave, present

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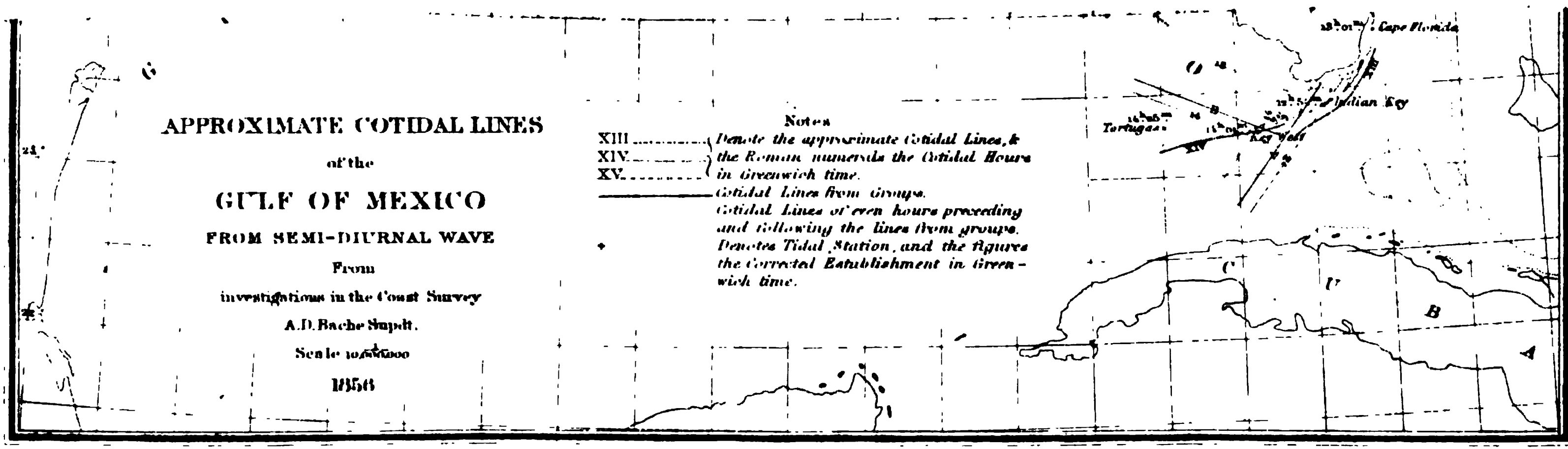
APPROXIMATE COTIDAL LINES
of the
GULF OF MEXICO
FROM SEMI-DIURNAL WAVE
From
investigations in the Coast Survey
A.D. Bache Supdt.
1856
Notes
XIII
XIV
XV
Denote the approximate Cotidal Lines, & the Roman numerals the Cotidal Hours in Greenwich time.
Cotidal Lines from Groups.
Cotidal Lines of even hours preceding and following the lines from groups.
Denotes Tidal Station, and the figures the Corrected Establishment in Greenwich time.
Cape Florida
Indian Key
Key West
Tortugas
XIV
B
C
A

considerable discrepancies from the observed. The least difference is $8^{m}.5$, and the greatest $67^{m}$.

These groups are marked upon the chart, diagram No. 6, and the cotidal hour next before and after the mean cotidal line of the groups. An approximation to the cotidal lines from these data is also shown upon the chart. The approximate cotidal hours of the several stations are marked upon the chart.

The cotidal lines of thirteen and fourteen hours only appear on the coast of the Florida Keys, that of sixteen hours is well marked near Egmont Key (Tampa), and passes around the shores of the great bay between Louisiana and Florida, to near Southwest Pass. The line of eighteen hours is at the head of the bight between St. George's and Cedar Keys, and seventeen in that near Cat Island. The lines of sixteen and twenty-one hours succeed each other closely in the bay to the westward of Southwest Pass.

In comparing the two sets of cotidal lines for the diurnal and semi-diurnal waves, we find a general resemblance in the great bay between the western coast of Florida and the eastern coast of Louisiana, the lines of twenty-four, twenty-five, and twenty-six of the diurnal tide on the eastern side of the bay corresponding generally with sixteen, seventeen, and eighteen of the semi-diurnal tide, and twenty-five and twenty-six hours of the diurnal tide on the western side of the bay corresponding generally to sixteen and seventeen of the semi-diurnal. On the southern coast of Florida, by the Keys, on the contrary, the lines of nineteen, twenty, twenty-one, twenty-two, and twenty-three hours succeed each other rapidly between Cape Florida and the Tortugas in the diurnal series, while thirteen and fourteen hours only occur along the same shores in the semi-diurnal tide. On the contrary, in the bay between Louisiana and Texas, or west of Southwest Pass, the lines of twenty-five, twenty-six, and twenty-seven hours only occur at considerable distances in the diurnal system, while sixteen, seventeen, eighteen, nineteen, twenty, and twenty-one occur in the same space, between Southwest Pass and the Brazos Santiago, in the semi-diurnal tide.

I shall continue to collect observations bearing upon the facts discussed in this paper, and to have them worked up, so as to amend the imperfections of the approximate results now presented. There are simultaneous observations at some of the stations which were formerly

examined with but little satisfaction as to the conclusions; these will now be resumed, and may throw additional light upon the results at some of the doubtful stations. The interference problems will be taken up when more extended data give better hopes of a satisfactory solution of them.

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## 2. Notes on the Progress made in the Coast Survey, in Prediction Tables for the Tides of the United States Coast. By A. D. Bache, Superintendent U. S. Coast Survey. [Communicated by Authority of the Treasury Department.]

As soon as tidal observations had accumulated sufficiently to make the task a profitable one, I caused them to be treated, under my immediate direction, by the methods in most general acceptance. The observations of Old Point Comfort, Virginia, were among the earliest used for this purpose, and the labors of Commander Charles H. Davis, U. S. N., then an assistant in the Coast Survey, were directed to their reduction, chiefly by the graphical methods pointed out by Mr. Whewell. This work was subsequently continued by Mr. Lubbock's method, by Mr. Henry Mitchell, and next the tides of Boston harbor were taken up, as affording certain advantages in the observations themselves which could not be claimed for those of Old Point.

The system of Mr. Lubbock is founded on the equilibrium theory, and in it the inequalities are sought by arranging the elements of the moon's and sun's motions, upon which they depend. Having obtained the coefficient of the half-monthly inequality of the semi-diurnal tide at Boston, from seven years' observations, through the labors of the tidal division, and approximate corrections for the parallax and declination, I was much disappointed in attempting the verification by applying them to individual tides for a year during which we had observations. There was a general agreement on the average, but discrepancies in the single cases, which were quite unsatisfactory. Nor were these discrepancies without law, as representing their residuals by curves did not fail to show. By introducing corrections for declination and parallax of the moon increasing and decreasing, we reduced

these discrepancies; but still the results were not sufficient approximations.

With the numerical reductions of the observations before referred to, was commenced, in 1853, under my immediate direction, by Mr. L. W. Meech, a study of the theory of the tides, directed chiefly to the works of Bernouilli, La Place, Airy, Lubbock, and Whewell. The immediate object which I had in view was the application of the wave theory to the discussion of our observations. I thought that the mind of an expert mathematician, directed entirely to the theoretical portions of this work, with directions by a physicist, and full opportunities of verifying results by extended series of observations, the computations of which should be made by others in any desired form, would give, probably, the best results in this combined physical and mathematical investigation.

The general form of the different functions expressing the tidal inequalities is the same in the different theories, and may be said on the average to be satisfactory as to the laws of change which these inequalities present. Whether we adopt, with La Place, the idea that periodical forces produce periodical effects, or, with Airy, the idea that the tidal wave arrives by two or more canals, or, with Bernouilli and Lubbock, the results of an equilibrium spheroid, or, with Whewell, make a series of inequalities, semi-menstrual, parallax, and declination, with different epochs, we arrive at the same general results, that the heights and times of high water may be represented by certain functions, with indeterminate coefficients, in the form of which the theories in a general way agree. By forming equations from the observations, and obtaining the numerical values of the coefficients, by the method used so commonly in astronomical computations, the result is accomplished.

A general consideration of the co-ordinates in space of the moon and sun, without any special theory, would lead to the same result, representing the luni-tidal interval by series of sines and co-sines with indeterminate coefficients.

Calling $I$ the luni-tidal interval from observation, $\lambda$ the mean luni-tidal interval, $H$ the clock time of observation, $l't$ the moon's longitude, $P'$ the moon's parallax, and $\delta P'$ the hourly variation of the

moon's parallax, we have, for the formula representing the correction for half-monthly inequality,

$$s \sin 2H + s_1 \cos 2H;$$

for the moon's parallax correction,

$$p\,(P' - 57') + p_2\,(P' - 57') \sin 2H + p_3\,(P' - 57') \cos 2H;$$

for the correction for hourly difference of the moon's parallax,

$$p_1\,(\delta P') + p_4\,(\delta P') \sin 2H + p_5\,(\delta P') \cos 2H;$$

and for the moon's declination corrections, including the rate of change,

$$d \sin 2l't + d_1 \cos 2l't + q_1 \sin 2l't \sin 2H + q_2 \sin 2l't \cos 2H$$
$$+ q_3 \cos 2l't \sin 2H + q_4 \cos 2l't \cos 2H.$$

There are corresponding terms for the inequalities produced by the sun's action.

The whole formula takes the form,

$$I = \lambda + s \sin 2H + s_1 \cos 2H \left.\right\} \text{Mean interval and half-monthly inequality correction.}$$

$$\left.\begin{array}{l} p\,(P' - 57') + p_2\,(P' - 57') \sin 2H \\ \qquad + p_3\,(P' - 57') \cos 2H \end{array}\right\} \text{Moon's parallax correction.}$$

$$p_1\,(\delta P') + p_4\,(\delta P') \sin 2H + p_5\,(\delta P') \cos 2H \left.\right\} \text{Hourly diff. of Moon's parallax correction.}$$

$$\left.\begin{array}{l} d \sin 2l't + q_1 \sin 2l't \sin 2H + q_2 \sin 2l't \cos 2H \\ d_1 \cos 2l't + q_3 \cos 2l't \sin 2H + q_4 \cos 2l't \cos 2H \end{array}\right\} \text{Moon's declination corrections.}$$

$$\left.\begin{array}{l} + t_1 \sin lt \sin 2H + t_2 \sin lt \cos 2H \\ + t_3 \cos lt \sin 2H + t_4 \cos lt \cos 2H \end{array}\right\} \text{Sun's parallax corrections.}$$

$$\left.\begin{array}{l} + Q_1 \sin 2lt \sin 2H + Q_2 \sin 2lt \cos 2H \\ + Q_3 \cos 2lt \sin 2H + Q_4 \cos 2lt \cos 2H \end{array}\right\} \text{Sun's declination corrections.}$$

The grouping of the observations of one year at Boston, to apply this method, the formation of the equations, and their solution by the method of indirect elimination, has been the work of Mr. R. S. Avery, who has labored most assiduously and successfully, ingeniously checking his work where the system of checks could be applied, at every step. He has determined the values of $\lambda$ and of the coefficients for Boston as follows: —

$$\lambda = +\,38.47, \quad d = -\,3.17, \quad d_1 = -\,35.62,$$

$$p = -\,0.93, \quad p_1 = -\,1.56, \quad s = -\,19.49, \quad s_1 = +\,11.97,$$

$$p_2 = +\,1.31, \quad p_3 = -\,1.21, \quad p_4 = +\,0.23, \quad p_5 = +\,0.60,$$

$$q_1 = -\,7.17, \quad q_2 = +\,1.81, \quad q_3 = +\,2.91, \quad q_4 = -\,1.99,$$

$$t_1 = +\,5.14, \quad t_2 = +\,2.26, \quad t_3 = -\,0.76, \quad t_4 = -\,1.37,$$

$$Q_1 = -\,21.25, \quad Q_2 = +\,28.39, \quad Q_3 = +\,27.10, \quad Q_4 = +\,23.13.$$

There are propositions for facilitating this work, growing out of the experience acquired in the computations, but requiring more examination than they have yet received before pronouncing upon them. It is possible that, by applying Lubbock's method of averages to some of the terms, approximate values may be found more readily than by the method we have employed. Two additional terms for the sun's declination, $D \sin 2\, l\, t$, and $D_1 \cos 2\, l\, t$, will be introduced. I present to the Association the tables computed by Mr. Avery for applying this method to the prediction of the tides at Boston harbor.

In order to test the coefficients, computations were made for different parts of the months of the year 1853 for which we have observations. Transit C was used as the transit of reference.

The differences between the predicted and observed results are shown in the annexed table, the first column of which contains the dates, the second the computed, the third the observed, and the fourth the observed less the computed results.

From this table it appears that in twenty pairs of tides, the morning and afternoon results being grouped in the fifth column to get rid of the diurnal inequality, there are two differences of less than $2^{m.}$, thirteen of more than $2^{m.}$ and less than $4^{m.}$, three of more than $4^{m.}$ and less than $10^{m.}$, and two of more than $10^{m.}$. The probable error of the prediction of a single pair of tides is $4^{m.}.12$.

These laborious researches are still in progress, but I have thought that the results already obtained required a notice of them, and a recognition of the labors of Messrs. Meech and Avery.

*Comparison of Observed and Predicted Times of High Water, Boston, Massachusetts.*

| Date. 1858. | | Time of High Water. Predicted. | Observed. | Difference Obs. Pr. | Mean of Pairs. |
|---|---|---|---|---|---|
| | | h. m. | h. m. | m. | m. |
| March | 21 | 8 4.7 | 8 3 | — 1.7 | |
| " | 21 | 20 32.9 | 20 32 | — 0.9 | — 1.3 |
| " | 25 | 11 28.0 | 11 21 | — 7.0 | |
| " | 25 | 23 49.8 | 23 48 | — 1.8 | — 4.4 |
| " | 29 | 2 21.7 | 2 20 | — 1.7 | |
| " | 29 | 14 45.3 | 14 42 | — 3.3 | — 2.5 |
| April | 2 | 6 16.9 | 6 21 | 4.1 | |
| " | 2 | 18 51.5 | 18 59 | 7.5 | 5.8 |
| " | 6 | 10 19.8 | 10 18 | — 1.8 | |
| " | 6 | 22 40.2 | 22 36 | — 4.2 | — 3.0 |
| June | 21 | 11 18.4 | 11 18 | — 0.4 | |
| " | 21 | 23 44.7 | 23 49 | 4.3 | 2.0 |
| " | 25 | 2 34.5 | 2 39 | 4.5 | |
| " | 25 | 15 2.3 | 15 3 | 0.7 | 2.6 |
| " | 29 | 5 57.7 | 6 7 | 9.3 | |
| " | 29 | 18 24.3 | 18 37 | 12.7 | 11.0 |
| July | 3 | 9 27.4 | 9 31 | 3.6 | |
| " | 3 | 21 52.2 | 21 53 | 0.8 | 2.2 |
| " | 7 | 0 0.1 | 0 3 | 2.9 | |
| " | 7 | 12 10.3 | 12 12 | 1.7 | 2.3 |
| September | 24 | 3 59.4 | 4 7 | 7.6 | |
| " | 24 | 16 24.8 | 16 24 | — 0.8 | 3.4 |
| " | 28 | 7 39.7 | 7 44 | 4.3 | |
| " | 28 | 20 11.6 | 20 15 | 3.4 | 3.9 |
| October | 2 | 11 6.1 | 11 4 | — 2.1 | |
| " | 2 | 23 31.1 | 23 30 | — 1.1 | — 1.6 |
| " | 6 | 1 44.7 | 1 40 | — 4.7 | |
| " | 6 | 14 7.7 | 14 7 | — 0.7 | — 2.7 |
| " | 10 | 5 24.5 | 5 19 | — 5.5 | |
| " | 10 | 17 57.8 | 17 58 | 0.2 | — 2.7 |
| December | 21 | 3 7.2 | 3 9 | 1.8 | |
| " | 21 | 15 28.4 | 15 30 | 1.6 | 1.7 |
| " | 25 | 6 32.6 | 6 31 | — 1.6 | |
| " | 25 | 19 0.7 | 18 52 | — 8.7 | — 5.2 |
| " | 29 | 10 22.4 | 10 26 | 3.6 | |
| " | 29 | 22 53.3 | 22 42 | —11.3 | — 3.9 |
| January | 2 | 1 29.4 | 1 2 | —27.4 | |
| " | 2 | 13 54.0 | 13 41 | —13.0 | —20.2 |
| " | 6 | 4 45.8 | 4 53 | 7.2 | |
| " | 6 | 17 33.9 | 17 30 | — 3.9 | 1.7 |

Final Mean, . . . . . . . . . . . 0.5

Probable error, minutes . . . . . . . . . 4.12

Number of differences less than two minutes = 2

Number of differences more than two minutes and less than four = 13

" " " four " " " ten = 8

" " " ten " = 2

3. OBSERVATIONS TO DETERMINE THE CAUSE OF THE INCREASE OF SANDY HOOK, MADE BY THE COAST SURVEY FOR THE COMMISSIONERS ON HARBOR ENCROACHMENTS OF NEW YORK. By A. D. BACHE, Superintendent U. S. Coast Survey.

*Abstract.*

IT is known as one of the developments of the Coast Survey, that the peninsula of Sandy Hook is gradually increasing, growing to the northward in the main ship-channel. A spot north of the Hook, where there was forty feet of water when Captain Gedney made his survey, in less than ten years was nearly bare at low water. The importance of determining the cause of this increase, as leading to the means of controlling it, cannot be over-estimated. The Commissioners on Harbor Encroachments had early attended to this matter, and requested that the necessary observations for its investigation should be made. These were made, under my immediate direction, by Henry Mitchell, one of the sub-assistants in the Coast Survey, with all desirable zeal and ability. Various causes had been assigned for this growth, by the action of the waves and winds sometimes on the outer side and sometimes on the inside of the Hook. The effect of the opening and closing of Shrewsbury Inlet had also been insisted upon. To examine these and other probable causes, laborious observations of tides and currents had been made in the vicinity, at stations marked upon the map now exhibited to the Association. Careful measurements of the low-water line had also been made in connection with these observations, and with others of the force and direction of the wind. Objects easily distinguished from the sand, and of various specific gravities and shapes, had been deposited near the shore of the Hook to determine the power and direction of transportation of matter along the shores of the Hook. It is easy to see how laborious all of these observations are, and that some of them are obtained with considerable danger. Hence the credit to be given to Mr. Mitchell may be measured. The results of these observations have not yet been worked out in all their detail, but the conclusions from them are perfectly safe, and are of the highest importance. It turns out that this growth of the Hook is not an accidental phenomenon, but goes on regularly, and according to determinable laws. The amount of in-

crease depends upon variable causes, but the general fact is, that it increases year by year; and the cause of this is a remarkable northwardly current, the amount and duration of which these observations assign along both shores of the Hook, the outer one extending across the whole breadth of False Hook channel with varying velocity, and the one inside of the Hook extending nearly one third of the distance across Sandy Hook bay. These currents run to the north during both ebb and flood tide, with varying rates, and result from those tides directly and indirectly. The inner current is the one by which the flood and ebb tides draw, by the lateral communication of motion, the water from Sandy Hook bay; and the outer is similarly related to those tides as they pass False Hook channel. The velocities and directions which have been found, prove this conclusively. An important observation for navigation results from this; for more than seven hours out of the twelve there is a northwardly current running through False Hook channel, which assists vessels entering New York harbor on the ebb tide, and is to be avoided in passing out with the ebb. This northwardly current runs on the inside for eleven hours out of the twelve. It is the conflict of these two northwardly currents outside and inside, and the deposit of the materials which they carry to the point of the Hook, which cause its growth. Within a century it has increased nearly a mile, and at the rate of about one sixteenth of a mile, on the average, in twelve years. Flynn's Knoll, on the north side of the main ship-channel, does not give way as much as the point of the Hook advances. The importance of watching this movement cannot, therefore, be overstated. The mode of controlling the growth is obvious from the result obtained. The observations are still continued, to obtain the necessary numerical results.

4. Notice of Observations to determine the Progress of the Tidal Wave of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments. By A. D. Bache, Superintendent U. S. Coast Survey.

*Abstract.*

Professor Bache explained the importance of a knowledge of the movement of the tide-wave up the Hudson River to the determination of the shore line of New York bay and harbor, and the subject of encroachment upon the area of the harbor, and stated that the New York Commissioners had directed a full series of observations to be made for the examination of this point in the bearing just referred to, and also on the character of the improvements projected for the Hudson River at the Overslaugh, and indeed in the whole distance from Troy to New Baltimore. Nine tidal stations were in the course of occupation between Governor's Island, New York, and Greenbush, opposite Albany. At the two terminal stations Saxton's self-registering gauges were placed, and he had expected to invite the members to see the Albany gauge; but the late freshet in the river had required its removal for the present. Professor Bache explained the selections made of the localities of the tidal stations, and the reasons for their special positions, and stated that the results of the work would hereafter be laid before the Association.

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5. Supplement to the Paper on the "Secular Variation in the Magnetic Declination on the Atlantic and Gulf Coast of the United States, from Observations in the 17th, 18th, and 19th Centuries," published in the Providence Proceedings of the Association. By Charles A. Schott, U. S. Coast Survey. (By Permission of the Superintendent of the U. S. Coast Survey.)

The former discussion of the secular change of magnetic declination having pointed out where new observations would be of special

value, such additional determinations have been made by myself at a number of stations, under the direction of Professor Bache. By their introduction, the conclusions previously arrived at have been materially improved in accuracy, and have received important additions, which it is the purpose of this paper briefly to state, with special reference to the formula and notation used in the former discussion.

This supplement is confined to the subdivisions (*b*) and (*d*), and includes new determinations of the declination at Burlington, Vt., Boston, Providence, New Haven, New York, Philadelphia, Cape May, and Washington City, made during the months of August and September, 1855.

The results of the rediscussion are presented in the following tables, which partly take the place of those given on pages 168 and 169 of the Proceedings of the Ninth Meeting.

*Synopsis of Results of the Discussion for Secular Variation at Thirteen Stations.*

| No. | Station. | Latitude. | Longitude. | Declination. | | |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° | | |
| 1 | Burlington, Vt. | 44 28 | 73 10 | $D = +8.22 + 0.0494(t-1830)$ | $+0.000831(t-1830)^2$ | |
| 2 | Boston, | 42 20 | 71 2 | “ $+8.33+0.0622$ “ | $+0.000596$ | “ |
| 3 | Cambridge, | 42 23 | 71 7 | “ $+8.55+0.0702$ “ | $+0.000720$ | “ |
| 4 | Providence, | 41 50 | 71 24 | “ $+7.51+0.0664$ “ | $+0.000852$ | “ |
| 5 | New Haven, | 41 17 | 72 55 | “ $+5.40+0.0475$ “ | $+0.000814$ | “ |
| 6 | New York, | 40 43 | 74 0 | “ $+5.07+0.0536$ “ | $+0.000800$ | “ |
| 7 | Hatborough, | 40 7 | 75 8 | “ $+2.86+0.0683$ “ | $+0.001169$ | “ |
| 8 | Philadelphia, | 39 58 | 75 10 | “ $+2.52+0.0595$ “ | $+0.001232$ | “ |
| 9 | Cape May, | 38 56 | 74 57 | “ $+0.88+0.0532$ “ | $+0.000809$ | “ |
| 10 | Washington, | 38 53 | 77 1 | “ $+0.88+0.0412$ “ | $+0.001080$ | “ |
| 11 | Charleston, | 32 45 | 79 51 | “ $-3.33+0.0485$ “ | $+0.000722$ | “ |
| 12 | Mobile, | 30 14 | 88 0 | “ $-7.24+0.0072$ “ | $+0.000123$ | “ |
| 13 | Havana, Cuba, | 23 9 | 82 22 | “ $-6.08+0.0098$ “ | $+0.000255$ | “ |

| No. | Station. | $\varepsilon_0$ | $T$ | $d$ | Annual Variation. | $V$ in 1850. |
|---|---|---|---|---|---|---|
| | | ′ | | ° | | ′ |
| 1 | Burlington, Vt. | ± 10 | 1800.3 | +7.49 | $V = +0.049 + 0.00166\ (t-1830)$ | +4.9 |
| 2 | Boston, | ± 12 | 1777.8 | +6.72 | “ $+0.062 + 0.00119$ “ | +5.2 |
| 3 | Cambridge, | ± 5 | 1781.2 | +6.83 | “ $+0.070 + 0.00144$ “ | +5.9 |
| 4 | Providence, | ± 7 | 1791.0 | +6.14 | “ $+0.070 + 0.00178$ “ | +6.0 |
| 5 | New Haven, | ± 11 | 1800.8 | +4.71 | “ $+0.047 + 0.00163$ “ | +4.8 |
| 6 | New York, | ± 15 | 1796.5 | +4.15 | “ $+0.054 + 0.00160$ “ | +5.2 |
| 7 | Hatborough, | ± 8 | 1799.5 | +1.87 | “ $+0.068 + 0.00224$ “ | +6.8 |
| 8 | Philadelphia, | ± 21 | 1805.9 | +1.80 | “ $+0.060 + 0.00246$ “ | +6.5 |
| 9 | Cape May, | .... | 1797.1 | +1.00 | “ $+0.053 + 0.00162$ “ | +5.1 |
| 10 | Washington, | .... | 1810.9 | +0.49 | “ $+0.041 + 0.00216$ “ | +5.0 |
| 11 | Charleston, | ± 10 | 1796.4 | −4.16 | “ $+0.048 + 0.00144$ “ | +4.6 |
| 12 | Mobile, | .... | 1800.6 | −7.35 | “ $+0.007 + 0.00024$ “ | +0.7 |
| 13 | Havana, Cuba, | .... | 1810.8 | −6.17 | “ $+0.010 + 0.00051$ “ | +1.2 |

The average $\tau$ from the first seven stations is 1792.4, and from the last six 1803.6, and the mean $\tau = 1797.6 \pm 1.8$ years (see Proceedings of Ninth Meeting, p. 171, note). To the northeastward of Philadelphia, within the geographical limits of the discussion, we may therefore assume the minimum to have taken place about five years earlier, and to the southward of that place, about the same number of years later than the mean epoch.

Two observations by Dr. J. Locke, not obtained in time for introduction into the discussion, are represented by the above formulæ as follows: — At Burlington, Vt., June 26th, 1845, observed declination 9° 22′ west, computed 9° 11′ west; at Cambridge, June 2d, 1845, observed declination 9° 32′ west, computed 9° 49′ west. The last observation appears to give too low a value, since Mr. Bond had obtained 9° 39′ in the preceding year.

(To *d.*) The re-discussion of the coefficient $C'$ in regard to the geographical position of the stations furnished the following numerical result for the coefficients $x$, $y$, $z$, $u$ and $v$: —

$$10{,}000\ C' = +\ 556 - 10.4\ (l - 37°.5) - 44.4\ (m - 76°.1) \cos l$$
$$- 1.65\ (l - 37°.5)^2 - 0.08\ (m - 76°.1)^2 \cos^2 l\ ;$$

or,

$$C' = +\ 0.0556 - 0.00104\ \lambda - 0.00444\ \mu - 0.000165\ \lambda^2$$
$$- 0.000008\ \mu^2\ ;$$

(see Proceedings of the Ninth Meeting, p. 174, note;) which equation satisfied the coefficients $C'$ (or the former $y$) as follows: —

| No. | Station. | $C'$ | $C'$ computed. | $\Delta$ |
|---|---|---|---|---|
| 1 | Burlington, Vt., | 0.0494 | 0.0496 | +0.0002 |
| 2 | Boston, | 0.0622 | 0.0636 | +0.0014 |
| 3 | Cambridge, | 0.0702 | 0.0629 | −0.0073 |
| 4 | Providence, | 0.0664 | 0.0634 | −0.0030 |
| 5 | New Haven, | 0.0475 | 0.0600 | +0.0125 |
| 6 | New York, | 0.0536 | 0.0577 | +0.0041 |
| 7 | Hatborough, | 0.0683 | 0.0553 | −0.0130 |
| 8 | Philadelphia, | 0.0595 | 0.0551 | −0.0044 |
| 9 | Cape May, | 0.0532 | 0.0534 | +0.0002 |
| 10 | Washington, D. C., | 0.0412 | 0.0507 | +0.0095 |
| 11 | Charleston, | 0.0485 | 0.0431 | −0.0054 |
| 12 | Mobile, | 0.0072 | 0.0129 | +0.0057 |
| 13 | Havana, Cuba, | 0.0098 | 0.0105 | +0.0007 |

The last column gives $\varepsilon_{C''} = \pm\ 0.0057$, which approaches still closer to $\varepsilon_y = \pm\ 0.0046$, as deduced from the differences at each sta-

tion. The second co-efficient $C''$ has been deduced from the mean of the values for $C'$ and $C'$ computed, and was found as follows:—

| | | |
|---|---|---|
| From | Burlington, | $n = 0.016$ |
| " | Boston, | 0.010 |
| " | Cambridge, | 0.012 |
| " | Providence, | 0.013 |
| " | New Haven, | 0.015 |
| " | New York, | 0.016 |
| " | Hatborough, | 0.019 |
| " | Philadelphia, | 0.021 |
| " | Cape May, | 0.015 |
| " | Washington, | 0.023 |
| " | Charleston, | 0.016 |
| " | Mobile, | 0.014 |
| " | Havana, | 0.025 |

where $C'' = n\ C'$.

The values just deduced should be used in connection with the formulæ

$$D = C + C'\ (t - 1830) + C''\ (t - 1830)^2$$

and

$$v = C' + 2\ C''\ (t - 1830).$$

The following comparison of the latest observations, with the values computed for the same date, will show that the latter exceed the former, almost without exception,—an indication that the rate of increase has begun to lessen, and that the expectation of the point of inflexion in the curve, representing the rate of change about the time $1867 \pm 15$ was not premature (see Proceedings of Ninth Meeting, page 167).

| Station. | *D* computed for 1855.5. | *D* observed in 1855.5. | C. — O. |
|---|---|---|---|
| Burlington, Vt., | $+10^{\circ}.02$ | $+\ 9^{\circ}.95$ | $+0^{\circ}.07$ |
| Albany, | 8.45 | 7.91 | +0.54 |
| Salem, | 11.12 | 10.83 | +0.29 |
| Boston, | 10.30 | 10.23 | +0.07 |
| Cambridge, | 10.76 | 10.90 | —0.14 |
| Providence, | 9.68 | 9.52 | +0.16 |
| Nantucket, | 10.15 | 9.98 | +0.17 |
| New Haven, | 7.16 | 7.05 | +0.11 |
| New York, | 6.97 | 6.72 | +0.25 |
| Philadelphia, | 4.85 | 4.53 | +0.32 |
| Washington, | + 2.63 | + 2.40 | +0.23 |

The average difference is $+\ 0^{\circ}.19 = 11'$. The precise date of

the maximum annual change cannot now be ascertained, and must be left to a future series of observations; but it is recommended, in the application of the formulæ for any period subsequent to 1850, to compute the change for a corresponding interval prior to that date, and add it to the declination in 1850.

Thus, for example, the declination at Boston in 1870 will be found by computing the increase for twenty years prior to 1850, and adding the same to the declination for 1850; or $9^\circ.81 + 1^\circ.48 = 11^\circ\ 18'$ W.

Without stepping off the positive ground heretofore occupied, it will be interesting to remark the following epochs: —

| | | Differences. |
|---|---|---|
| Deduced maximum declination in | 1679 ± 10 years. | |
| | | 62 years. |
| Known first point of inflexion, | 1741 ± 10 " | |
| | | 57 " |
| Known minimum declination, | 1798 ± 2 " | |
| | | 52 " |
| Supposed second point of inflexion, 1850. | | |

From which it would seem that the periods are diminishing, or the velocity of the secular variation is increasing, which latter remark is sustained by the comparison of $V_{1741} = -4'.6$ with $V_{1850} = +6'.8$ or $+5'.9$, as deduced from all the Northern stations. The prediction of the next maximum is too hazardous to deserve our attention at present.

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## 6. Discussion of the Secular Variation of the Magnetic Inclination in the Northeastern States. By Charles A. Schott, U. S. Coast Survey. (Communicated by Permission of Professor A. D. Bache, Superintendent U. S. Coast Survey, and by Authority of the Treasury Department.)

The following paper on the secular variation of the magnetic inclination near the Atlantic coast, between latitudes 38° and 44°, forms a part of the general discussion of the magnetic observations of the Coast Survey, under the direction of the Superintendent, the publication of which was commenced in the Superintendent's annual report for 1855, and which will be continued in the report for 1856.

While the observations of declination reach back as far as the seventeenth century, and are quite numerous since the latter half of the eighteenth, the observations for inclination are of but recent date. Near our Atlantic coast, thirty or thirty-five years include the whole period, taking no account of three observations about 1782, at Cambridge. Fortunately for our knowledge, the secular variation within this short period has passed a turning-point, the epoch of which has been fully established.

Here, as in the declination, Professor Loomis has contributed a large share in observing, collecting, and discussing magnetic dips, and we are also indebted to him for the construction of an isoclinal map. Professor Loomis says: "From these observations [collected by him], when compared with those of Long's expedition, we may assume the diminution of the dip from 1819 to 1839 to be at the rate of 1'.5 a year." (Silliman's Journal, XXXIX., 1840, On the Variation and Dip of the Magnetic Needle in the United States, by E. Loomis.)

It does not appear that later a second effort was made to follow these changes of the dipping needle, probably on account of the small change and stationary period soon afterwards reached.

It must be considered as fortunate, that the dip observations at the Toronto Observatory commenced as early as 1841, and therefore include the turning epoch, although from these observations alone it could not be clearly made out. Colonel Sabine remarks (page lxxxviii. of Observations made at the Magnetical and Meteorological Observatory at Toronto, Canada, Vol. II., 1843–45, London, 1853): "On a first inspection of the values of the inclination in the years from 1841 to 1852 inclusive, we might be led to infer that in 1843 or 1844 the secular change at Toronto reached a turning epoch, and that, from having been previously a decrease, it became subsequently an increase of inclination. It is possible, however, that the facts may admit, and may hereafter receive, a different explanation." He then goes on to show that the change may be owing to disturbances, and finally remarks: "In the mean time, considering the small amount of the apparent irregularities, together with the variety of needles employed in the observations of the different years and the consequent possibility of defective intercomparability, we may perhaps take as the best present approximation a uniform increase of inclination."

and in the Transactions of the American Philosophical Society, Vol. IX., 1846. They can be represented by the formula

$$I = 75^\circ.29 - 0.01441\ (t - 1840) + 0.001636\ (t - 1840)^2.$$

The following table contains the observed and computed inclinations: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1841.5 | 75.28 | 75.27 | —0.01 |
| 1842.5 | 75.27 | 75.26 | —0.01 |
| 1843.0 | 75.26 | 75.26 | 0.00 |
| 1843.5 | 75.24 | 75.25 | +0.01 |
| 1844.5 | 75.23 | 75.25 | +0.02 |
| 1845.5 | 75.26 | 75.26 | 0.00 |
| 1846.5 | 75.25 | 75.26 | +0.01 |
| 1847.5 | 75.26 | 75.27 | +0.01 |
| 1848.5 | 75.30 | 75.28 | —0.02 |
| 1849.5 | 75.31 | 75.30 | —0.01 |
| 1850.5 | 75.33 | 75.32 | —0.01 |
| 1851.5 | 75.34 | 75.34 | 0.00 |
| 1852.5 | 75.34 | 75.36 | +0.02 |

The probable error of any single result is $\pm\ 0'.6$.

### Secular Change of the Magnetic Dip at Albany and Greenbush, New York.

The observations were extracted from the Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. III., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. IV., 1847; and Coast Survey Report for 1855.

They are represented by the formula

$$I = 74^\circ.70 - 0.0086\ (t - 1840) + 0.00257\ (t - 1840)^2,$$

which expression represents the observations as follows: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1833.4 | 74.85 | 74.86 | +0.01 |
| 1837.1 | 74.76 | 74.74 | —0.02 |
| 1842.0 | 74.70 | 74.69 | —0.01 |
| 1844.5 | 74.69 | 74.71 | +0.02 |
| 1855.6 | 75.19 | 75.19 | 0.00 |

The probable error of any single result is $\pm\ 0'.9$.

### Secular Change of the Magnetic Dip at Cambridge, Mass.

The observations were taken from the Memoirs of the American Academy, 1846; Encyclopædia Metropolitana, 1848; Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. IV., 1847; Smithsonian Contributions to Knowledge, Vol. III., 1852; and Coast Survey Report for 1855.

The observations have been represented by the following formula:

$$I = 74^\circ.34 - 0.02840\,(t - 1840) + 0.002400\,(t - 1840)^2.$$

The table shows the comparison of the observed and calculated inclinations: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| 1839.7 | 74°.31 | 74°.35 | +0°.04 |
| 1840.5 | 74.36 | 74.33 | —0.03 |
| 1841.6 | 74.22 | 74.30 | +0.08 |
| 1842.4 | 74.24 | 74.28 | +0.04 |
| 1844.9 | 74.30 | 74.26 | —0.04 |
| 1845.5 | 74.32 | 74.26 | —0.06 |
| 1846.7 | 74.21 | 74.26 | +0.05 |
| 1855.6 | 74.48 | 74.48 | —0.00 |

The probable error of any single value is $\pm$ 1′.8.

### Secular Change of the Magnetic Dip at Providence, R. I.

The observations can be found in Silliman's Journal, Vol. XLIII., 1842; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. VII., 1840; and in the Coast Survey Report for 1855.

They are represented by the formula

$$I = 73^\circ.99 - 0.0040\,(t - 1840) + 0.00141\,(t - 1840)^2.$$

Comparison of observed and computed values: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| 1834.6 | 74°.05 | 74°.06 | +0°.01 |
| 1839.7 | 73.99 | 73.99 | 0.00 |
| 1842.5 | 74.00 | 73.99 | —0.01 |
| 1855.6 | 74.27 | 74.27 | 0.00 |

$$\varepsilon_0 = \pm\ 0'.7.$$

### Secular Variation of the Magnetic Dip at West Point and Cold-spring, N. Y.

References to observations: Silliman's Journal, Vol. XLIII., 1842; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 73^\circ.43 - 0.00165\,(t - 1840) + 0.002080\,(t - 1840)^2.$$

The agreement with the observed dip is as follows: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1833.9 | 73.53 | 73.52 | —0.01 |
| 1839.8 | 73.46 | 73.43 | —0.03 |
| 1840.5 | 73.33 | 73.43 | +0.10 |
| 1842.5 | 73.51 | 73.44 | —0.07 |
| 1855.6 | 73.91 | 73.91 | 0.00 |

The probable error of any single value is $\pm\ 3'.1$.

### Secular Change of the Magnetic Dip at New Haven, Conn.

References to observations: Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. IV., 1847; and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 73^\circ.42 + 0.0020\,(t - 1840) + 0.00117\,(t - 1840)^2.$$

Comparison of observed and computed dips: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1839.7 | 73.45 | 73.42 | —0.03 |
| 1842.4 | 73.44 | 73.43 | —0.01 |
| 1844.5 | 73.40 | 73.45 | +0.05 |
| 1848.6 | 73.54 | 73.52 | —0.02 |
| 1855.6 | 73.74 | 73.73 | —0.01 |

$$\varepsilon_0 = \pm\ 2'.2.$$

SECULAR CHANGE OF THE MAGNETIC DIP AT NEW YORK.

References of observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; Ibid., Vol. IX., 1846; a communication by Professor Hansteen, dated October 15th, 1854; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. XLIII., 1842; Ibid., Vol. XXII., 1832; Ibid., Vol. IV., 1847; and Coast Survey Report for 1855.

These observations have been represented by the formula

$$I = 72^\circ.69 - 0.00491\,(t - 1845) + 0.001141\,(t - 1845)^2,$$

as follows: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1823.9 | 73.24 | 73.31 | +0.07 |
| 1831.3 | 73.00 | 72.98 | —0.02 |
| 1833.4 | 73.03 | 72.91 | —0.12 |
| 1835.0 | 72.86 | 72.86 | 0.00 |
| 1839.7 | 72.87 | 72.75 | —0.12 |
| 1841.3 | 72.68 | 72.73 | +0.05 |
| 1842.5 | 72.64 | 72.71 | +0 07 |
| 1844.4 | 72.62 | 72.70 | +0.08 |
| 1845.5 | 72.68 | 72.69 | +0.01 |
| 1846.6 | 72.65 | 72.69 | +0.04 |
| 1845.6 | 72.83 | 72.77 | —0.06 |

The probable error of any single value is $\pm$ 3′.3. The above formula, when transformed for the epoch 1840, becomes

$$I = (i_0 - 5\,y + 25\,z) + (y - 10\,z)\,(t - 1840) + z\,(t - 1840)^2;$$

or numerically,

$$I = 72^\circ.75 - 0.01632\,(t - 1840) + 0.001141\,(t - 1840)^2.$$

SECULAR CHANGE OF THE MAGNETIC DIP AT PHILADELPHIA, PA.

References to observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VII., 1840; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. XLII., 1842; Ibid., Vol. IV., 1847; Observations at Magnetic Observatory, Girard College, Philadelphia, 1840–45 (Washington, 1847); and Coast Survey Report for 1855.

The observations have been represented by the formula

$$I = 71^\circ.99 + 0.0010\,(t - 1840) + 0.00124\,(t - 1840)^2.$$

The positive sign of $y$ probably arises from too small a dip in 1834,

which also causes the minimum to shift to an earlier date than the other stations indicate.

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1834.5 | 72.00 | 72.02 | +0.02 |
| 1840.2 | 72.00 | 71.99 | —0.01 |
| 1841.3 | 71.97 | 71.99 | +0.02 |
| 1842.5 | 72.00 | 72.00 | 0.00 |
| 1843.6 | 71.96 | 72.01 | +0.05 |
| 1844.4 | 72.03 | 72.02 | —0.01 |
| 1846.4 | 72.02 | 72.05 | +0.03 |
| 1855.7 | 72.30 | 72.31 | +0.01 |

The probable error of any single value is $\pm$ 1′.0.

If we consider the important series of dips observed at the Girard Observatory by itself, we find the secular change between 1842 and 1844 is much masked by the annual inequality and other irregularities, as will be seen from the separate results. The quarterly means probably indicate the minimum about the autumn of 1843; in the recapitulation, however, I have preferred to give the result derived from the discussion of all observations.

### Secular Change of the Magnetic Dip at Washington, D. C.

References to observations: Silliman's Journal, Vol. XXXIX., 1840; Ibid., Vol. I., 1846; Ibid., Vol. IV., 1847; Transactions of the American Philosophical Society, Vol. VII., 1840; Ibid., Vol. IX., 7th series, 1844; Ibid., Vol. VIII., 1843; Senate Document, 2d Session, 28th Congress, 1844-45; and Coast Survey Report of 1855.

The following formula represents these observations:

$$I = 71^\circ.29 - 0.01496\,(t - 1840) + 0.001728\,(t\ 1840)^2;$$

with the differences: —

| $t$ | $I$ Observed. | $I$ Computed. | $\Delta$ |
|---|---|---|---|
| | ° | ° | ° |
| 1839.2 | 71.29 | 71.30 | +0.01 |
| 1841.0 | 71.30 | 71.27 | —0.03 |
| 1842.5 | 71.22 | 71.26 | +0.04 |
| 1844.4 | 71.27 | 71.25 | —0.02 |
| 1851.5 | 71.32 | 71.34 | +0.02 |
| 1852.4 | 71 39 | 71.37 | —0.02 |
| 1855.7 | 71.47 | 71.48 | +0.01 |

The probable error of any single result is $\pm$ 1′.2.

### Secular Change of the Magnetic Dip at Baltimore, Md.

References to observations: Transactions of the American Philosophical Society, Vol. V., 1835; Ibid., Vol. VIII., 1843; Ibid., Vol. IX., 1846; and Silliman's Journal, Vol. IV., 1847.

For want of an observation at the present time, the formula expressing the variation in the dip can only be approximate; the observations are well represented by

$$I = 71^\circ.72 - 0.0357\,(t - 1840) + 0.00104\,(t - 1840)^2,$$

which agrees very well in regard to the curvature ($z$) with the rest of the stations.

## Recapitulation of Results.

### TABLE No. I.

*Geographical Position of Stations, and Number of Observations for Dip at each.*

| No. | Station. | Latitude. | Longitude. | No. of Observations. |
|---|---|---|---|---|
| | | ° ′ | ° ′ | |
| 1 | Toronto, Canada, | 43 33 | 79 20 | 15 |
| 2 | Albany (and Greenbush), N. Y., | 42 37 | 73 44 | 9 |
| 3 | Cambridge (and Boston), Mass., | 42 22 | 71 07 | 17 |
| 4 | Providence, R. I., | 41 50 | 71 24 | 4 |
| 5 | West Point (and Coldspring), N. Y., | 41 25 | 73 57 | 6 |
| 6 | New Haven, Conn., | 41 17 | 72 55 | 10 |
| 7 | New York, N. Y., | 40 43 | 74 00 | 22 |
| 8 | Philadelphia, Pa., | 39 58 | 75 10 | 45 |
| 9 | Washington (and Georgetown), D. C., | 38 53 | 77 01 | 17 |
| 10 | Baltimore, Md., | 39 18 | 76 37 | 16 |

### TABLE No. II.

*Formula expressing the Inclination at the several Stations, arranged in the order of their Magnetic Latitude.*

| | |
|---|---|
| Toronto, | $I = 75^\circ.29 - 0.0144\,(t - 1840) + 0.00164\,(t - 1840)^2$. |
| Albany, | " 74.70 — 0.0086 " + 0.00257 " |
| Cambridge, | " 74.34 — 0.0284 " + 0.00240 " |
| Providence, | " 73.99 — 0 0040 " + 0.00141 " |
| West Point, | " 73.43 — 0.0016 " + 0.00208 " |
| New Haven, | " 73.42 + 0.0020 " + 0.00117 " |
| New York, | " 72.75 — 0 0163 " + 0.00114 " |
| Philadelphia, | " 71.99 + 0.0010 " + 0.00124 " |
| Washington, | " 71.29 — 0.0150 " + 0.00173 " |

The agreement of the values for $y$ and $z$ must be considered as very satisfactory. The shifting of the epoch $t_0$ by a few years would give equal sign to $y$ for all stations; but by so doing nothing is gained. The coefficients $z$, expressing the curvature, are still more accordant than the $y$'s.

TABLE No. III.

*Showing the Probable Error $\epsilon_0$ of any single Determination for Dip (or in many cases of the Mean of several Observations at the same time), the epoch T of the Minimum Dip, and the Annual Variation V in the current Year.*

| Station. | $\epsilon_0$ | $T$ | $V$ 1856. |
|---|---|---|---|
| Toronto, | ± 0′.6 | 1844.7 | + 2′.1 |
| Albany, | 0.9 | 1841.7 | + 4.3 |
| Cambridge, | 1.8 | 1845.9 | + 2.9 |
| Providence, | 0.7 | 1841.4 | + 2.9 |
| West Point, | 2.4 | 1840.4 | + 3.9 |
| New Haven, | 2.2 | 1839.2 | + 2.3 |
| New York, | 3.3 | 1847.1 | + 1.2 |
| Philadelphia, | 1.0 | 1839.6 | + 2.2 |
| Washington, | ± 1.2 | 1844.3 | + 2 4 |
| Mean, | ± 1.6 | 1842.7 ± 0.7 | + 2.7 |

Professor Hansteen, in his paper in the *Astronomische Nachrichten*, alluded to before, obtained for New York a result contradictory of the above well-established one, and supposes the dip to attain a *maximum* value in 1822.3. This is due to the small number and uncertainty of the observations used. The recent observations have been furnished to him at his request, and he will probably see cause to modify his former conclusions on this point. We see thus that the inclination has become stationary 1842.7 — 1797.2, or 45½ years after the declination was in a similar condition.

In the Northeastern States the inclination reached a minimum about the middle of the year 1843, and from a previous decrease has become increasing since that time, with a gradually increasing rate.

The formulæ deduced apply with certainty for ten or fifteen years before and after the year 1843, and in the absence of other information may be extended as far back as the commencement of the present century.

I append a few remarks in reference to the secular change in the Western part of this continent. While at St. Louis and other places in the Western States the dip was decreasing since 1819 until about 1842, we find the same thing to have taken place on the Western coast; and from the scanty material available in that region, we have sufficient proof of the fact, that since the close of the last century the dip was decreasing at an average rate of about 2′ a year, and, after having become stationary nearly about the same time as on the Atlantic coast, is now on the increase. Thus at San Diego the minimum

took place about 1844, and even as high north as Sitka this epoch appears to have obtained. Professor Hansteen, in No. 947 *Ast. Nach.*, calculates for this place,

$$I = 75^\circ.84 + 0.0084\ (t - 1840) + 0.00068\ (t - 1840)^2,$$

and consequently $T = 1833.8 \pm 6.4$ years.

Thus it appears with great probability that, over the northern part of the United States, from ocean to ocean, the secular change of the inclination has been following a uniform law, reversing its direction about the same period.

In regard to the Southern States, there is not a sufficient number of observations to permit a conjecture as to the secular variation of the dipping needle.

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### 7. On the General Distribution of Terrestrial Magnetism in the United States, from Observations made in the United States Coast Survey and Others. By A. D. Bache, Superintendent, and J. E. Hilgard, Assistant.

During the progress of the Coast Survey within the last twelve years, observations of the magnetic elements have been made, under special instructions from the Superintendent, at most of the astronomical stations, and near many capes and harbors where a knowledge of the variation of the compass was requisite for the use of navigation. The number of magnetic stations now amounts to about one hundred and sixty, distributed (irregularly as yet) along the entire sea-coast of the United States, on a great portion of which magnetic observations were now made for the first time. The object of this paper is to deduce from the Coast Survey observations, in connection with others of recent date, the general distribution of terrestrial magnetism in the United States, as far as the data available will warrant the conclusions.

These observations have been discussed from time to time under the immediate direction of the Superintendent of the Coast Survey, with the double purpose of determining the distribution of magnetism in different sections of the United States, and the local irregularities. Observations have also been repeated at many places where the discrepancies indicated the necessity for such a course, and generally

resulted in throwing the discrepancies upon the existence of local attraction.

The area under discussion is so large, and the observations comparatively so sparse, that nothing more than the *general* distribution can at present be attempted. Local deviations from the general system, of greater or less magnitude and extent, are apparent in the table of residuals given at the close of this paper, which must be ascribed mainly to local attraction, since the errors of observation are far less in amount, and point out localities where additional observations will be most useful.

The results of the Coast Survey observations are given in Table I., which gives the latitude and longitude of the stations, the declination, dip, and horizontal intensity of the earth's magnetic force, the date of the observations, and a reference to the particular locality, its geology, and other attending circumstances.

The record of these observations, and the details of methods and instrumental constants, will shortly be published as part of the Coast Survey records and results, for the publication of which Congress has provided. A brief notice will therefore suffice here.

In observing the *declination*, the magnetic meridian has generally been obtained by means of collimator magnets, using Gauss and Weber's transportable magnetometer, while the astronomical meridian was derived from the triangle sides of the Coast Survey, or obtained by direct observations.

The *dip* has been observed with needles of from six to ten inches in length, made by Gambey and by Barrow. Two needles have generally been used,—or when one only was employed, it has been carefully tested and compared.

The *horizontal intensity* has been determined in absolute measure by vibrations and deflections, according to the methods of Gauss and Lamont. The units of measure are those used in the British surveys.

From the agreement of repeated observations, it is inferred that the uncertainty of the observations at a particular spot does not exceed one or two minutes of arc in the declination and dip, and $\frac{1}{500}$ part of the horizontal force.

The data derived from other sources that are combined with the Coast Survey observations are all of recent date, in order not to introduce much uncertainty into the reduction to a common period. They are:—

1. Observations by Lieutenant (now Colonel) LEFROY of the R. B. Artillery, in Canada, along the St. Lawrence, and at Toronto; being part of those published by Colonel SABINE in the Philosophical Transactions of 1846 and 1849.

2. Observations made in connection with the Survey of the North-eastern Boundary. — *Ibid.*

3. Observations of Horizontal Intensity in Waterville, Maine. By Professor G. W. KEELY, in 1847, *Philosophical Transactions*, 1848.

4. Observations by the late Dr. JOHN LOCKE, in various parts of the United States, especially in Ohio and the Northwestern States. *American Philosophical Transactions*, 1846, and *Smithsonian Contributions*, 1852. The values of horizontal intensity in this series are originally expressed in terms of the force at Cincinnati, and have been converted into British units through the observations at Toronto, which is one of the stations.

5. Observations in various parts of the Middle and Western States. By Professor E. LOOMIS, *American Philosophical Transactions*, Vols. VII. and VIII.

6. Observations made on the Mexican Boundary Surveys, under the direction of Major W. H. EMORY, U. S. A., recently presented by him to the *American Academy of Sciences.*

7. Observations made by Captain WHIPPLE's party in the Pacific Railroad Explorations near the 35th parallel of latitude. This series, not heretofore published, was kindly furnished us by Captain A. W. WHIPPLE, U. S. Top. Engineers, and is given in full in Table II. It will be seen that a large number of the stations are at a great elevation above the sea level. The effect of elevation on the action of the earth's magnetism has generally been found insensible, and in the absence of any known correction the observations have necessarily been used without regard to height. The observations have been made with a Fox dip-circle, and Cambridge, Mass. was used as reference station for the intensity. The numbers in the table denoting the total intensity may be considered as referring to the arbitrary scale, in which the total force at London is 1.372, with the usual uncertainty on account of secular variation.

For use on the map they have been multiplied by 7.41 to give the total intensity in British units, and by the cosine of the dip for the horizontal force. The factor 7.41 is the ratio of 13.32, the total intensity

in British units at Cambridge, from observations by Mr. W. C. Bond and the Coast Survey observations in the vicinity, to 1.798, the reference number in the table.

8. Table III. gives some observations of declination not before published, collected from various sources for this discussion.

## Correction for Secular Variation.

The observations in the discussion have been reduced to the common date of January, 1850, by the best values for the annual change that could be arrived at.

The annual change for the declination and dip has been used as found in the discussion by Mr. C. A. Schott, communicated to the Association by authority of Prof. Bache, and printed in the present volume.

For the Northwestern States we deduce, from scanty data, and have applied, an annual change of from $1'.6$ to $2'$ decrease of easterly declination.

Determinations of intensity in absolute measure are of so recent a date that but little is known in regard to its secular variation. Observations of the horizontal force at Toronto, Boston, New York, Philadelphia, and Pascagoula, made during the interval between 1843 and 1855, concur in showing a decrease of nearly $\frac{1}{1000}$ part of the force per year. If we suppose the total force to remain constant, the known increase of the dip would account for a rather larger diminution of the horizontal component; and since it is probable that the total intensity is likewise slightly on the increase, the result obtained from our scanty data may be considered sufficiently well established to be used.

Our knowledge of the secular changes on the Western coast and in the Territories is so deficient, that no satisfactory reduction can be applied to the observations. The changes, however, are known to be small, and the observations do not differ greatly in date. Their mean date is about 1852, which may be considered as the period to which the Western part of our map corresponds more nearly than to 1850.

## Construction of Map.

In the construction of the lines on the map, both the graphic and analytical methods have been used.

Observations within limited spaces were united into groups, by taking the arithmetical means; a number of such groups were combined

by conditional equations of the second degree, amounting to an interpolation by second differences.

The several systems of groups were so arranged as to overlap, and the slight disagreement in the joining was adjusted by an interpolation partly graphic and partly arithmetical.

When the latitude and longitude of stations have appeared unsuitable co-ordinates of position, owing to the stations being distributed in an oblique direction to the meridian, they were carefully projected on a map and referred by measurement to an assumed axis of co-ordinates in any convenient linear measure; the lines deduced from the conditional equations so formed being projected according to the same system, the latitude and longitude of points in them could be read off and tabulated, the artificial system serving only as a convenient means of interpolation.

On the accompanying maps the lines of equal declination, dip, and horizontal intensity have been drawn only as far as they were warranted by observations. For places within the range of the lines, approximate values may be readily obtained by graphical interpolation.

Table IV. gives the differences between the observed values at the Coast Survey stations reduced to 1850, and the corresponding values on the maps. It will be seen that there are a few large residuals, sometimes exceeding 2° in declination, 1° in dip, and $\frac{1}{20}$ of the horizontal force, which belong to isolated stations (see Mount Pleasant, No. 5, and Patuccawa, No. 15), or very limited localities (see stations near Cape Ann, Nos. 20 to 24); in these cases, local attraction is too apparent to allow the observations to be used in the construction of the map.

We find further, that, in certain more extended localities, the residuals, in declination, amounting in the average to about 20′ or 25′, have one sign, indicating a more general deviation from a regular system. Thus the observed declination near New York, eastward to Black Rock, and westward to Princeton, are larger than those deduced, while near Cape May, in the lower part of New Jersey and Delaware, they are less; in the western part of Massachusetts they are greater, in the eastern part they are less. For the want of more ample material, especially of observations in the interior, no attempt has at present been made to represent these irregularities in the system of lines. They are greatest in amount in the Eastern and Middle States, where

the average of the residuals, irrespective of sign, is 16′, excluding the class first noticed. Along the shores of the Gulf of Mexico it is 6′, and on the Western coast it amounts to 10′.

The residuals of the *dip* observations are less than those of the declination, amounting in the average to 7′, and there are a less number of large disturbances. When we consider that the disturbing polarities probably act nearly in the plane of the horizon, we may conclude that the irregularities of the dip should bear a still smaller proportion to those of the declination; and we see that the constant instrumental errors, which are larger for the dip than for the declination, are not without sensible effect on the magnitude of the residuals.

Upon the same consideration, it will not be surprising that the residuals of the horizontal force observations are larger in proportion than those of the dip, being in the mean about the sixtieth part of the actual values of the horizontal intensities. A variation of 10′ in the dip would correspond to one of the hundred and twentieth part of the horizontal force.

## Comparison of Maps.

A comparison of the maps herewith presented with other similar ones that have heretofore been constructed, cannot fail to be interesting and instructive.

*Declination.* Allowing for the change in ten years, the lines on Professor Loomis's map for 1840 (*Silliman's Journal*, Vol. XL.) agree well with the present map; considering the comparatively small number and often unreliable character of observations they were based upon, the agreement is remarkable, and leads to the hope that valuable results may be derived from the recent observations made in connection with surveys of public lands in the country west of the Mississippi, in which Burts's solar compass has been used to a great extent.

Colonel Sabine's chart of the declination in the Atlantic Ocean (*Philosophical Transactions*, 1849) covers only the northeastern portion of our map, which in that portion in part is based upon the same observations used by him. The agreement is not as close as it would be, if, in reducing the observations of 1844 and 1845 to 1840, the epoch of the map, the secular change used had not been considerably in error, as already noted in Mr. Schott's paper on the secular change of the declination (*Proc. Am. Association*, *9th Meeting*). As it is, the

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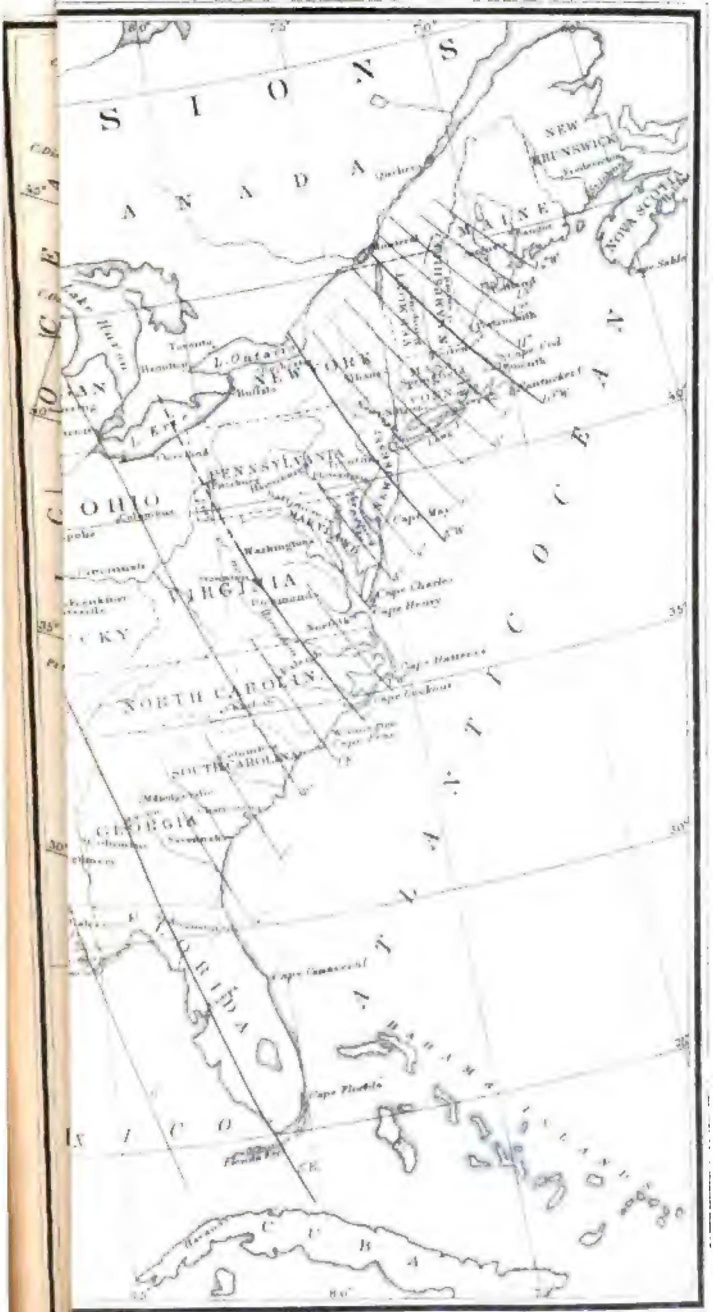
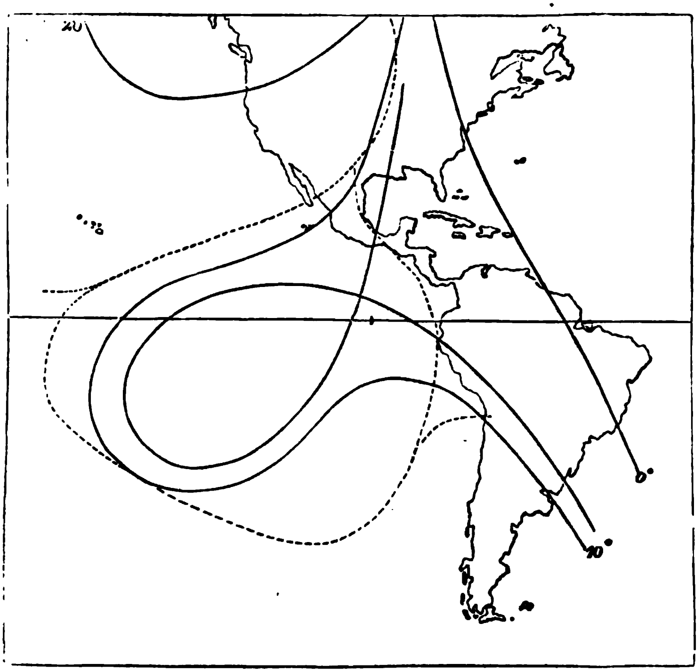


lines agree well in direction, but occupy too nearly the same position for the differences of epoch.

The most important comparison is that with Gauss's maps of the computed values of the declination, dip, and horizontal intensity. They are the only ones in which the three elements have been considered as having a necessary connection with each other, and while they may be considerably in error as to absolute quantities, the agreement in *form* with the lines on our maps, derived purely from observations, is strong evidence of the general correctness of the assumptions upon which they are based.

The data for the declination were taken by GAUSS from BARLOW'S map in the *Philosophical Transactions*, 1833, of which the mean epoch cannot be later than 1830. The system of lines derived by Gauss on theoretical considerations differs in certain localities materi-




ally from that of Barlow. The annexed diagram exhibits the essential difference in form. While Barlow's line of 10° (indicated by a

broken line) has several branches which diverge tangentially, according to Gauss such a divergence cannot take place; but when there is a space within which the declination is less than outside any portion of its limiting line, that line must form a loop, the two branches intersecting nearly at right angles, as shown in the looped line of 8° 45′. It must be remembered that the region in question is one where very few observations had been made in 1830, and that Barlow's system is probably quite as much as that of Gauss a theoretical interpolation, though graphically performed; and that hitherto there have been no observed facts, in the region of Texas and New Mexico at least, upon which a decision could be based.

A form of branching similar to that on Barlow's map, and at variance with Gauss's theory, occurs in HANSTEEN's *Erdmagnetismus*, and has been preserved on a recent map of the declination in his *Magnetiske Inclinations Forandring*, 1855.

It will be seen that, if Barlow's system represents the forms correctly, the line of 9° easterly declination along the coast of Texas should turn to the *southeast*, while the line on our map, fixed by numerous observations, turns decidedly to the *southwest*, in conformity with Gauss's system. In going westward along the Mexican boundary there is not a decrease and subsequent increase, as Barlow's map indicates, but a steady increase, established by the observations along that boundary. The general agreement in form between the lines on our map and the Gauss system is striking. Observations in Central America would at present be of the greatest value in deciding the matter under discussion. The isolated observation at Panama, Table III., has aided greatly in fixing the direction of the line of 7° east, determining that it still turns to the southeast.

On the Atlantic coast the Gauss lines of declination agree well in position with ours, allowing for the difference of epoch. On the western coast they are farther to the south, which seems contrary to what is supposed to be the secular change.

*Dip.* With LOOMIS's map before quoted, and SABINE's map of the dip in British America, *Philosophical Transactions*, 1846, the agreement is excellent. The Gauss lines agree well in form, but differ from 2° to 2½° in the amount of dip. This is due to the errors of Horner's map, from which they are derived, and on which the lines are about 2½° out of position. It must be remembered that they were

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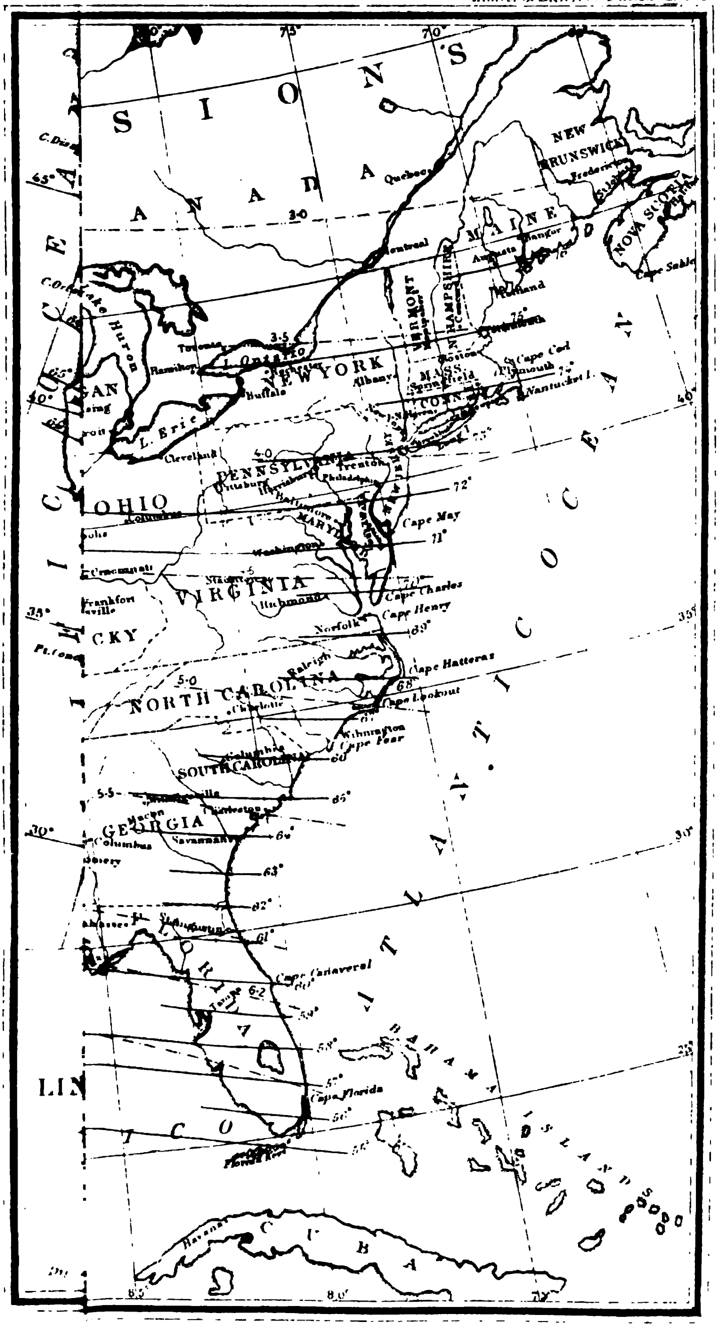

altogether interpolated, no observations of dip in the United States being known when Horner's map was constructed.

*Horizontal Intensity.* For a comparison of this element, we have only Gauss's chart, on which the lines are affected by the errors of the dip lines, by means of which they have been derived from Sabine's general map of the total intensity for 1836. The values of the Gauss lines being expressed in the arbitrary scale, multiplied by 1000, we reduce them to absolute measure through the observations at Toronto, where in 1844 the total intensity in the arbitrary scale was 1.836, the dip 75° 13′.4, the horizontal force 3.54 in absolute measure in British units, giving a multiplier of 7.56 for the arbitrary scale, or 0.00756 for Gauss's values. We find thus 3.78 equivalent to Gauss's line of 500, along which the actual horizontal force is 4.24 to 4.30; in the same place the dip is really 71° 30′, and on Gauss's map 73° 15′.

Corresponding differences exist in other parts of the map.

*Supplementary Note.* The following results of observations recently made in Mexico for the Smithsonian Institution are added here, with the permission of the Secretary, from his eleventh report to the Regents. They afford a strong confirmation of the conclusions arrived at in this discussion.

The observations were made under the direction of Baron Mueller, of Marseilles, by Mr. A. Sonntag, during the autumn of 1856, with the modern improved instruments belonging to the Smithsonian Institution.

| Name of Station. | Latitude. | Longitude. | Declination East. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|
| | ° ′ | ° ′ | ° ′ | ° ′ | |
| Vera Cruz, | 19 12 | 96 9 | 8 17 | 43 58 | 7.533 |
| Potrero, | 18 56 | 96 48 | 8 39 | 42 51 | 7.576 |
| Orizaba, | 18 53 | 97 4 | 8 28 | 42 51 | 7.579 |
| St. Andrès Chalchecomula, | 18 59 | 97 14 | 8 13 | 42 38 | 7.594 |
| Mirador, | 19 13 | 96 37 | 8 2 | 43 48 | 7.528 |
| City of Mexico, | 19 26 | 99 5 | 8 46 | 41 26 | 7.581 |

TABLE I. *Magnetic Observations made during the Progress of the*

| No | Name of Station. | Latitude. | Longitude | Declination West. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 1 | Mount Harris, | 44 39 9 | 69 8.5 | 14 34.6 | 76 14.1 | 3.236 |
| 2 | Ragged Mountain, | 44 12.7 | 69 8.7 | 14 16.8 | 75 41.2 | 3.339 |
| 3 | Camden Village, | 44 12.0 | 69 5.0 | 13 57.1 | 75 41.5 | 3.340 |
| 4 | Mount Sebattis, | 44 9.1 | 70 4.5 | 12 53.5 | 75 40.6 | 3.411 |
| 5 | Mount Pleasant, | 44 1.6 | 70 49.0 | 14 32.1 | 76 1.5 | 3.211 |
| 6 | Cape Small, | 43 46.7 | 69 50.4 | 12 5.5 | 75 1.8 | 3.387 |
| 7 | Mount Independence, | 43 45.5 | 70 18.9 | 11 46.4 | 75 23.8 | 3.360 |
| 8 | Burlington, | 44 27.5 | 73 10.0 | 9 57.1 | 75 56 8 | 3.425 |
| 9 | Bowdoin Hill, | 43 38.8 | 70 16.2 | 11 41 1 | 75 14.1 | 3.450 |
| 10 | Richmond's Island, | 43 32.6 | 70 14.1 | 12 18 1 | 75 8.0 | 3.463 |
| 11 | Fletcher's Neck, | 43 26 8 | 70 20.2 | 11 17.5 | 75 18.3 | 3.440 |
| 12 | Kennebunk Port, | 43 21.4 | 70 27.8 | 11 23.6 | 75 14 1 | 3.448 |
| 13 | Mount Agamenticus, | 43 13.4 | 70 41.2 | 10 9 8 | 74 54.7 | 3.456 |
| 14 | Cape Neddick, | 43 11.6 | 70 36.1 | 11 9.0 | 74 57.9 | 3.516 |
| 15 | Patuccawa, | 43 7.2 | 71 11.5 | 10 42.8 | 76 49.5 | 3.020 |
| 16 | Kittery Point, | 43 4.8 | 70 42 7 | 10 30.2 | 74 57.2 | 3.500 |
| 17 | Mount Unkonoonuc, | 42 59.0 | 71 35.0 | 9 4.1 | 75 8.7 | 3.469 |
| 18 | Isle of Shoals, | 42 59.2 | 70 36.5 | 10 3.5 | 74 44.1 | 3.481 |
| 19 | Plum Island, | 42 48.0 | 70 48.5 | 10 5.6 | 74 54.9 | 3.530 |
| 20 | Annis Squam, | 42 39.4 | 70 40.3 | 11 36.7 | | |
| 21 | Beacon Hill, | 42 36.2 | 70 38.3 | 11 21.1 | 74 26 4 | 3.617 |
| 22 | Baker's Island Light, | 42 32.2 | 70 46.8 | 12 17.0 | 74 18.6 | 3.674 |
| 23 | Fort Lee, | 42 31.9 | 70 52.1 | 10 14.5 | | 3.487 |
| " | " " | " " " | " " | 10 49.7 | 75 36.9 | 3.489 |
| 24 | Coddon's Hill, | 42 30.9 | 70 50 9 | 11 49.8 | | |
| 25 | Little Nahant, | 42 26.2 | 70 55.5 | 9 40.9 | 74 29.5 | 3.555 |
| 26 | Dorchester Heights, | 42 20 0 | 71 2 2 | 9 31 4 | 74 12 7 | 3.587 |
| | " " | " " | " " | 10 13.7 | 74 29.5 | 3.544 |

*U. S. Coast Survey, from* 1844 *to* 1856, A. D. BACHE, *Superintendent.*

| No. | Date. | Locality, Geology, and Remarks. |
|---|---|---|
| 1 | 1855.7 | Near the geodetic station on the Dixmont Hills, Penobscot Co., Me. Talcose slate of a gray color, running E. N. E. and W. S. W. with a dip to the N. N. W. from 80° to 90°. |
| 2 | 1854.7 | Waldo Co., Me. Gneiss, impregnated with oxide of iron. Near the geodetic station on the summit. |
| 3 | 1854.8 | On Penobscot Bay, Waldo Co., Me. On grounds of Mr. Hugier. |
| 4 | 1853.6 | At the foot of Mt. Sebattis, town of Wales, Me., in the meadow of Colonel H. Marr. On the top of the hill the declination was found to vary from 9° to 14° in a space of 50 yards. The hill is composed of granite with quartz veins and detached masses of mica. |
| 5 | 1851.6 | Town of Denmark, Me. Granite. |
| 6 | 1851.8 | Town of Phippsburg, Me., on the property of Mr. R. Morrison, 50 yards south of geodetic station. |
| 7 | 1849.8 | Town of Falmouth, Me., in a field of Mr. Joseph Hobbes, close to the old road. Drift, clay, and gravel. |
| 8 | 1855.7 | At the flag-staff on Camp ground, city of Burlington, Vt. Drift, clay, and sand 60 or 80 feet deep, overlying limestone and sandstone. |
| 9 | 1851.6 | In the grounds of J. B. Brown, city of Portland. Drift, sand, and gravel. |
| 10 | 1850.7 | In a field near the dwelling-house of Dr. Cummings. Talcose and mica slate, intersected by a large trap dyke. |
| 11 | 1850.7 | Mouth of Saco River, extremity of south point. Metamorphic slate. |
| 12 | 1851.7 | 150 yards N. N. W. of Kennebunk Port Observatory. Granite. |
| 13 | 1847.7 | On the summit of Mt. Agamenticus, town of York, Me. Sienite. |
| 14 | 1851.7 | Town of York, Me., in the field of J. Wyer, on the north side of Cape Neddick River, to the south of, and near, the road leading to the sea-shore. Granite underlying the soil. |
| 15 | 1849.6 | On the summit of the hill, in the town of North Deerfield, N. H. Mica slate. |
| 16 | 1850.7 | In an enclosure to the east of R. Gerrish's cottages. Argillaceous slate. |
| 17 | 1848.8 | The highest and most easterly summit of that name in Goffstown, 10 miles west of Manchester. Mica slate. |
| 18 | 1847.6 | On the south side of the harbor of Hog Island, 100 yards from the water. The Isles of Shoals are composed of mica slate and gneiss, with beds of granite ore, and some of them are traversed by dykes of trap. |
| 19 | 1850.7 | Near Thompson's hotel, on Plum Island, near Newburyport, Mass. Drift, covered with sea-sand. |
| 20 | 1849.7 | Sienite. The sienite of the coast of Massachusetts is frequently traversed by dykes of trap, porphyritic trap, &c. |
| 21 | 1849.7 | On the eastern point of Gloucester, Mass. Sienite. |
| 22 | 1849.7 | 100 yards from the Light, in the direction of Half-way Rock. Sienite. |
| 23 | 1849.6 } | Salem, Mass. Sienite. |
| " | 1855.7 } | Centre of Old Fort. Granite, partly covered by clay and sand. |
| 24 | 1849.7 | Marblehead, Mass. Sienite. |
| 25 | 1849.1 | On the hill. Sienite. |
| 26 | 1846.7 } | On South Boston heights, between Reservoir and Asylum for Blind. |
| " | 1855.7 } | Drift at least 90 feet deep, clay and sand mixed with pebbles. |

| No. | Name of Station. | Latitude. | Longitude. | Declination West. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 27 | Nantasket, | 42 18.2 | 70 54.0 | 9 37.4 | 74 15.9 | 3.566 |
| 28 | Blue Hill, | 42 12.7 | 71 6.5 | 9 13.5 | 75 5.6 | 3.519 |
| 29 | Beacon Pole Hill, | 41 59.7 | 71 26.7 | 9 27.0 | 74 21.9 | |
| 30 | Manomet Hill, | 41 55.6 | 70 35.1 | 9 16.9 | 74 30.0 | 3.640 |
| " | " " | " " | " " | | 74 1.2 | |
| 31 | Copecut Hill, | 41 43.3 | 71 3.3 | 9 8.8 | 74 9.5 | |
| 32 | Spencer's Hill, | 41 40.7 | 71 29.3 | 9 5.9 | 75 7.1 | |
| 33 | Shootflying Hill, | 41 41.1 | 70 20.5 | 9 37.4 | 74 23 3 | 3.657 |
| " | " " | " " | " " | 9 40.3 | 73 56.5 | 3.663 |
| 34 | Hyannis, | 41 37.9 | 70 18.1 | 9 21.6 | 73 49.2 | 3.682 |
| 35 | Fairhaven, | 41 37.4 | 70 53.7 | 8 54.2 | 74 40.0 | 3.592 |
| 36 | Tarpaulin Cove, | 41 28.1 | 70 45.1 | 9 12.1 | 73 49.8 | 3.696 |
| 37 | Indian Hill, | 41 25.7 | 70 40.3 | 8 43.9 | 73 41.4 | 3.734 |
| " | " " | " " | " " | 8 49.4 | 73 29.1 | 3.728 |
| 38 | Sampson's Hill, | 41 22.7 | 70 28.7 | 8 48.7 | 73 24.5 | 3 753 |
| 39 | Nantucket, | 41 17.5 | 70 5.7 | 9 14.0 | 73 44.4 | 3.653 |
| " | " | " " | " " | 9 58.6 | 74 0 6 | 3.626 |
| 40 | McSparran's Hill, | 41 29.7 | 71 27.1 | 8 48.5 | 73 47.6 | |
| 41 | Point Judith Light, | 41 21.6 | 71 28.6 | 8 59.7 | 73 45.1 | 3.788 |
| 42 | Providence, | 41 50.0 | 71 23 6 | 9 31.5 | 74 15.9 | 3.590 |
| 43 | Watch Hill, | 41 18.8 | 71 50.9 | 7 33.4 | | |
| 44 | Stonington, | 41 20.0 | 71 54.0 | 7 38.1 | 73 25.0 | |
| 45 | Groton Point, | 41 18.0 | 72 0.0 | 7 29.5 | | |
| 46 | Saybrook, | 41 16.0 | 72 20.0 | 6 49.9 | 74 33.8 | |
| 47 | Greenport, | 41 6.0 | 72 21.0 | 7 14.4 | 72 57.9 | |
| 48 | Sachem's Head, | 41 17.0 | 72 43.0 | 6 15.2 | | |
| 49 | Fort Wooster, | 41 16.9 | 72 53.2 | 7 27.2 | 74 16.6 | 3.667 |
| " | " " | " " | " " | 7 25.5 | 74 12.6 | 3.609 |
| 50 | Oyster Point, | 41 17.0 | 72 55 4 | 6 31.9 | 73 32.9 | 3.761 |
| " | " " | 41 16.9 | 72 55.5 | 7 2.7 | 73 44.5 | 3.690 |
| 51 | New Haven, | 41 18.0 | 72 54.3 | 6 37 9 | 73 31.9 | 3.768 |
| 52 | Milford, | 41 16.0 | 73 1.0 | 6 38.3 | | |
| 53 | Bridgeport, | 41 10 0 | 73 11.0 | 6 19.3 | 73 21.3 | |
| 54 | Black Rock, | 41 8.6 | 73 12.6 | 6 53.5 | | |
| 55 | Norwalk, | 41 7.1 | 73 24.2 | 6 49.4 | 73 9.8 | |
| 56 | Stamford, | 41 3 5 | 73 32 0 | 6 36 0 | 73 2.3 | 3.885 |
| 57 | Sawpits, | 40 59.5 | 73 39.4 | 5 58.0 | 72 53.4 | |
| 58 | Drowned Meadow, | 40 56.1 | 73 3.5 | 6 3.6 | | |
| 59 | Lloyd's Harbor, | 40 55 6 | 73 24.8 | 6 11 6 | 72 50 6 | 3.857 |
| 60 | Oyster Bay, | 40 52.3 | 73 31.3 | 6 50 5 | 72 58.8 | 3.894 |
| 61 | New Rochelle, | 40 52.5 | 73 47.0 | 5 29 5 | 72 44.0 | 3.845 |

| No. | Date. | Locality, Geology, and Remarks. |
| --- | --- | --- |
| 27 | 1847.7 | Drift and alluvium, resting on argillaceous slate. |
| 28 | 1845.8 | Dedham, Mass. Sienite. |
| 29 | 1844.9 | Near Cumberland Hill village, R. I. Granite. Iron ore occurs in the neighborhood. |
| 30 | 1845.7 | Near Plymouth, Mass. Drift. |
| " | 1846.7 | |
| 31 | 1844.8 | In the town of Fall River, Mass. Granite. Iron ore occurs in the neighborhood. |
| 32 | 1844.6 | Near East Greenwich, R. I. Metamorphic slate of carboniferous age. |
| 33 | 1845.6 | Near Barnstable, Mass. Drift. |
| " | 1846.7 | |
| 34 | 1846.6 | On a hill near Hyannis Point, about 60 feet high. Drift. |
| 35 | 1845.8 | Opposite New Bedford, Mass., 22 yards east of fort. Gneiss. |
| 36 | 1846.6 | Nashua, Mass., N. E. of the light, near south shore of the cove. Drift. |
| 37 | 1845.6 | Martha's Vineyard. Tertiary strata. |
| " | 1846.6 | |
| 38 | 1846.6 | On Chappaquiddick Island, opposite Edgarton, Martha's Vineyard. Drift. |
| 39 | 1846.6 | On the north beach, near the edge of the town, due N. of Mitchell's Observatory. Drift. |
| " | 1855.6 | Argillaceous sand, overlying a stratum of clay, resting on gneiss. |
| 40 | 1844.6 | South Kingston, R. I., in a field near the angle of the roads to Kingston and Wickford. |
| 41 | 1847.7 | 100 yards towards Beavertail Light. |
| 42 | 1855.6 | In the rear of Brown University, 198 feet from the central building. Quartz and gneiss rocks, and mica schist. |
| 43 | 1847.7 | Half a mile north of Watch Hill Lights, near Stonington, Conn. Granitic gneiss. |
| 44 | 1845.6 | Connecticut. Reddish granitic gneiss. |
| 45 | 1845.6 | Near New London, Conn. Whitish felspathic gneiss, with mica seams. |
| 46 | 1845.6 | Connecticut. Granitic gneiss. |
| 47 | 1845.6 | In Southold, Long Island. Drift. |
| 48 | 1845.7 | Connecticut. Reddish granitic gneiss. |
| 49 | 1847.7 | Near New Haven, Conn. Trap. |
| " | 1848.7 | |
| 50 | 1848.7 | Near New Haven in the meridian of Yale College Observatory. Trap. |
| " | 1855.6 | On Howard Avenue, 503 feet from high-water mark on foot of the avenue. Argillaceous soil. |
| 51 | 1848.6 | Near Pavilion Hotel. Sandstone underlying drift. |
| 52 | 1845.7 | Greenstone and chloritic slate. |
| 53 | 1845.7 | Conn. Gneiss and mica slate. |
| 54 | 1845.7 | Conn. Gneiss and mica slate. |
| 55 | 1844.7 | Conn. On Judge Isaac's Hill. Granite. |
| 56 | 1844.7 | Conn. In the rear of the Union Hotel. Granite. |
| 57 | 1844.7 | Steamboat-landing at Port Chester, Westchester Co., N. Y. Gneiss. |
| 58 | 1845.7 | Near Drowned Meadow village, north shore of Long Island. Drift and alluvium. |
| 59 | 1844.7 | Huntingdon, Long Island. Drift, with boulders. |
| 60 | 1844.7 | North shore of Long Island. Drift. |
| 61 | 1844.7 | About 100 yards south of the Neptune House, in New Rochelle, Westchester Co., N. Y. Gneiss and hornblendic rocks. |

| No. | Name of Station. | Latitude. | Longitude. | Declination West. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 62 | Sands' Point, | 40 52.0 | 73 43.0 | 7 14 6 | | |
| " | " " | " " | " " | 6 9.9 | | |
| 63 | Legget, | 40 48.9 | 73 53.0 | 5 41.0 | 72 52.7 | 3.976 |
| 64 | Greenbush, | 42 37.5 | 73 44.0 | 7 54.7 | 75 11.1 | 3.587 |
| 65 | Cold Spring, | 41 25.0 | 73 57.3 | 5 34.0 | 73 54.8 | 3.790 |
| 66 | Bloomingdale Asylum, | 40 48.8 | 73 57.4 | 5 9.7 | 72 39.0 | 4.009 |
| 67 | Columbia College, | 40 42.7 | 74 0.1 | 6 13.1 | 72 37.8 | |
| " | " " | " " | " " | 6 25.3 | | |
| 68 | Governor's Island, | 40 41.5 | 74 0.8 | 6 39.6 | 72 46.3 | 3.926 |
| 69 | Bedloe's Island, | 40 41.4 | 74 2.3 | 7 2.1 | 72 59.2 | 3.920 |
| 70 | Receiving Reservoir, | 40 46.7 | 73 57.8 | 6 28 0 | 72 44.4 | 3.938 |
| 71 | Newark, | 40 44.8 | 74 7.0 | 5 35.1 | 72 52.2 | 3.964 |
| 72 | Mount Prospect, | 40 40.3 | 73 57.7 | 5 54.7 | 72 27 6 | 4.053 |
| 73 | Cole, | 40 31.9 | 74 13.8 | 5 37.4 | 72 34.2 | 4.028 |
| 74 | Sandy Hook, | 40 28.0 | 73 59.8 | 5 51.0 | 72 37.9 | 4.077 |
| " | " " | 40 27.6 | 73 59.9 | 6 11.2 | 72 52.0 | 3.917 |
| 75 | Mount Rose, | 40 22.2 | 74 42.9 | 5 31.8 | 72 42 5 | 4.130 |
| 76 | White Hill, | 40 8.3 | 74 43.6 | 4 25.9 | 72 6.2 | 4.147 |
| 77 | Vanuxem, | 40 6.7 | 74 52.7 | 4 27.8 | 72 22.3 | 4.068 |
| 78 | Girard College, | 39 58.4 | 75 9.9 | 3 51.1 | 72 1.0 | 4.143 |
| " | " " | " " | 75 9.8 | 4 31.7 | 72 17.7 | 4.226 |
| 79 | Yard, | 39 58.3 | 75 22.9 | 6 42.3 | 73 1.4 | 3.876 |
| 80 | Chew, | 39 48.2 | 75 9 7 | 3 45.2 | 72 14.4 | 4.105 |
| 81 | Tucker's Island, | 39 30.8 | 74 16.9 | 4 27.8 | | |
| 82 | Tuckerton, | 39 36.1 | 74 19.5 | | 72 12.3 | 4.063 |
| 83 | Wilmington, | 39 44.9 | 75 33.6 | 2 30.7 | 71 25.4 | 4.236 |
| 84 | Sawyer, | 39 42.6 | 75 33.8 | 2 48.3 | 71 57.5 | 4.175 |
| 85 | Church Landing, | 39 40.6 | 75 30.4 | 5 49.1 | 71 22.0 | 4.311 |
| 86 | Fort Delaware, | 39 35.3 | 75 33.8 | 3 16.8 | 71 34.9 | 4.226 |

| No. | Date. | Locality, Geology, and Remarks. |
|---|---|---|
| 62 | 1845.7 | 40 yards E. N. E. from Sands' Point Light. Drift covered with alluvium. |
| " | 1847.8 | Near the Light-House. |
| 63 | 1847.8 | In a cove north of Rikers' Island, Long Island Sound. Gneiss covered with alluvium. |
| 64 | 1855.7 | Opposite Albany, N. Y., near Second Street, east of the Hudson River Railroad track. Clayey sand and dark-blue marl. |
| 65 | 1855.7 | Near the Hudson River, opposite West Point, on a bluff close to the village. Granite. |
| 66 | 1846.3 | Manhattan Island. Gneiss rock, underlying the soil. |
| 67 | 1844.7 | City of New York. Gneiss rock underlying drift, loam, and gravel. |
| " | 1845.7 | City of New York. |
| 68 | 1855.6 | New York harbor, between Fort Columbus and Castle William, in range with Trinity Church steeple and Battery flagstaff. Quartzose sand, overlying mica schist and granite. |
| 69 | 1855.6 | New York harbor, north side of Island, to the northward of the flagstaff. Quartzose sand, overlying metamorphic rock. |
| 70 | 1855.6 | City of New York, inside the Receiving Reservoir, near corner of 79th Street and 7th Avenue. Gneiss. |
| 71 | 1846.4 | New Jersey. Alluvial soil, sand, and gravel, superimposed on secondary red sandstone in place. |
| 72 | 1846.3 | Near Brooklyn, Long Island. Drift, with small boulders of granite and trap. |
| 73 | 1846.4 | In Westfield, southwestern part of Staten Island. Drift, with small boulders. |
| 74 | 1844.6 | 250 yards north of Light. Green-sand formation; alluvial sand. |
| " | 1855.6 | About 250 feet west of the Light-House on the top of a dune. The Hook consists of downs, and the quartz sand was found 25 feet deep. |
| 75 | 1852.6 | About 5 miles west of Princeton, N. J., in a field near the house of Thomas Hunt. Trap rock protruding through secondary red sandstone. |
| 76 | 1846.4 | Near Bordentown, N. J., on the bank of the Delaware River. Cretaceous marl. |
| 77 | 1846.5 | At Professor Vanuxem's, two miles above Bristol, on the Delaware River, 100 yards N. W. of the canal. Sand, clay, and gravel superimposed on metamorphic rock. |
| 78 | 1846.4 | In the yard of the Magnetic Observatory at Girard College, Philadelphia. |
| " | 1855.7 | To the northward and eastward of the College, within the enclosure, and in the road in the rear of the smaller building next to the College. Metamorphic rock, below gravel, etc. |
| 79 | 1854.8 | About 10 miles west of Philadelphia 250 yards E. S. E. of the trigonometrical station. |
| 80 | 1846.5 | Near Woodbury, N. J. Marl and green-sand of cretaceous formation. |
| 81 | 1846.9 | Entrance to Little Egg Harbor, N. J., N. W. point of island. Alluvium and white sand. |
| 82 | 1846.9 | |
| 83 | 1846.4 | Delaware. A hill 1¼ miles W. N. W. of the Town-Hall. Trap, covered with red clay. Local attraction. |
| 84 | 1846.4 | 3 miles south of Wilmington, Del. At the edge of the tertiary formation no rocks or boulders apparent. |
| 85 | 1846.4 | New Jersey, on Delaware River. Drift. Local attraction ascertained to exist by partial observations at these localities. |
| 86 | 1846.5 | Pea-patch Island, Delaware River. Alluvial mud at least 70 feet deep. |

| No. | Name of Station. | Latitude. | Longitude. | Declination West. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 87 | Hawkins, | 39 25.6 | 75 17.0 | 2 58.8 | 71 42.6 | 4.224 |
| 88 | Pine Mount, | 39 25.0 | 75 19.9 | 3 14.2 | 71 41.4 | 4.237 |
| 89 | Bombay Hook Light, | 39 21.8 | 75 30.3 | 3 18.5 | 71 39.5 | 4.201 |
| 90 | Port Norris, | 39 14.6 | 75 1.0 | 3 4.4 | 71 39.6 | 4.211 |
| 91 | Egg Island Light, | 39 10.5 | 75 8.0 | 3 3.0 | 71 45.1 | 4.206 |
| 92 | Town Bank, | 38 58.6 | 74 57.4 | 2 59.0 | 71 23.6 | 4.269 |
| 93 | Cape May Light (old), | 38 55.8 | 74 57.6 | 3 5.1 | 71 25.8 | 4.255 |
| " | " " " (new), | " " | 74 57.4 | 3 45.4 | 71 34.4 | 4.182 |
| 94 | Lewes's Landing, | 38 48.8 | 75 11.5 | 2 45.0 | | |
| 95 | Pilot Town, | 38 47.1 | 75 9.2 | 2 42.7 | 71 18.5 | 4.290 |
| 96 | Osborne's Ruin, | 39 27.9 | 76 16.6 | 2 32.4 | 71 47.6 | 4.143 |
| 97 | Susquehanna Light, | 39 32.4 | 76 4.8 | 2 13.7 | 71 52.1 | 4.086 |
| 98 | Finlay, | 39 24.4 | 76 31.2 | 2 14.6 | 71 52.9 | 4.059 |
| " | " | " " | " " | 2 18.5 | 71 45.2 | 4.170 |
| 99 | Pool's Island, | 39 17.1 | 76 15.5 | 2 29.3 | 71 52.1 | 4.117 |
| 100 | Rosanne, | 39 17.5 | 76 42.8 | 2 10.9 | 72 6.6 | 4.053 |
| 101 | Fort McHenry, | 39 15.7 | 76 34.5 | 2 18.6 | | |
| 102 | North Point, | 39 11.7 | 76 26.3 | 1 36.7 | 71 29.5 | 4.183 |
| " | " " | " " | " " | 1 39.6 | | |
| 103 | Bodkin Light, | 39 8.0 | 76 25.2 | 2 1.9 | 71 43.1 | 4.189 |
| 104 | Kent Island, (1) | 39 1.8 | 76 18.8 | 2 30.2 | 71 16.6 | 4.208 |
| 105 | South Base, Kent Island, | 38 53.8 | 76 21.7 | 2 24.3 | 71 37.0 | 4.206 |
| 106 | Taylor, | 38 59.8 | 76 27.6 | 2 14.4 | 71 40.2 | 4.231 |
| " | " | " " | " " | 2 18.0 | 71 19.3 | 4.221 |
| 107 | Marriott, | 38 52.4 | 76 36.2 | 2 9.4 | 71 10.9 | 4.260 |
| " | " | " " | " " | 2 5.0 | 71 13.0 | 4.228 |
| 108 | Webb's Hill, | 39 5.3 | 76 40.2 | 2 7.9 | 71 24.0 | 4.279 |
| 109 | Soper's Hill, | 39 5.1 | 76 56.7 | 2 7.1 | 71 56.5 | 4.142 |
| 110 | Hill's Hill, | 38 53.9 | 76 52.5 | 2 18.6 | 71 12.2 | 4.316 |
| 111 | Causten's Hill, | 38 55.5 | 77 4.1 | 1 11.3 | 71 18.9 | 4.229 |
| " | " " | " " | " " | 1 6.2 | 71 30.2 | 4.250 |
| " | " " | " " | " " | 1 6.0 | | |
| 112 | Washington City, | 38 53.2 | 77 1.2 | 5 44.2 | 71 27.0 | 4.337 |

| No. | Date. | Locality, Geology, and Remarks. |
|---|---|---|
| 87 | 1846.5 | Near Roadstown, N. J. Cretaceous formation. Some ferruginous sandstone in vicinity. |
| 88 | 1846.5 | An isolated hill near Greenwich, N. J. Cretaceous; unmagnetic iron ore. |
| 89 | 1846.5 | About 60 miles E. S. E. of the Light-House. Alluvial clay and sand. |
| 90 | 1846.5 | New Jersey. Cretaceous marl and sand. |
| 91 | 1846.5 | Delaware Bay, 60 yards S. by W. of Light-House. Cretaceous marl and sand. |
| 92 | 1846.5 | At Price's, near Cape May. Cretaceous marl and sand. |
| 93 | 1846.5 | 70 yards S. E. of Light-House. Cretaceous marl and sand. |
| " | 1855.6 | About 160 yards W. of the Light-House, near the sand dunes Quartz, sand, and broken shells. |
| 94 | 1846.5 | Near Cape Henlopen. |
| 95 | 1846.5 | On Cape Henlopen. Clay and sand. |
| 96 | 1845.5 | Near Abingdon, Md. Talcose slate and hornblende. |
| 97 | 1847.5 | A short distance to the N. W. of Light-House, at the mouth of Susquehanna River. Ferruginous clay and sand. |
| 98 | 1845.5 | On Cub Hill, the property of J. B. Finlay, 9 miles north of Baltimore, on the Harford Turnpike. Metamorphic rocks underlying gravel and sand. |
| " | 1846.3 | |
| 99 | 1847.5 | Chesapeake Bay, near the dwelling of P. Wethered, on the upper island. Alluvial clay and sand. |
| 100 | 1845.4 | On Prospect Hill, 5 miles from Baltimore, north of the old Frederick road. Alluvial clay and sand. |
| 101 | 1847.3 | Baltimore harbor; between the Hospital and western stable. Ferruginous sand and clay. |
| 102 | 1846.5 | Between the two Lights at the mouth of the Patapsco River. Ferruginous sand and clay. |
| " | 1847.3 | |
| 103 | 1847.3 | 20 yards S. S. E. from Light-House. Ferruginous sand and clay. |
| 104 | 1849.5 | North end of Kent Island, Chesapeake Bay. Ferruginous sand and clay. |
| 105 | 1845.4 | On the west shore of Kent Island, opposite Thomas's Point, 21 yards north of monument. Ferruginous sand and clay. |
| 106 | 1845.4 | On the north side of Severn River, opposite Annapolis, Md. Ferruginous sand and clay. |
| " | 1847.4 | |
| 107 | 1846.4 | A prominent hill near West River, Md., the property of Bushrod Marriott. Green-sand formation, ferruginous clay and marl. |
| " | 1849.5 | |
| 108 | 1850.9 | Anne Arundel Co., Md., near the Annapolis Railroad, 12 miles from Annapolis. Green-sand formation, ferruginous clay and marl. |
| 109 | 1850.6 | Prince George's Co., Md., 14 miles from Washington City, on the old Columbia road, property of J. B. Downs. Talcose slate. |
| 110 | 1850.7 | Prince George's Co., Md., 6 miles east of Washington City. Ferruginous clay and sand. |
| 111 | 1851.5 | Near Georgetown, D. C., 122 yards west of the geodetic station, in the grounds of J. H. Causten. Mica slate, with quartz veins, underlying ferruginous clay and gravel. |
| " | 1855.7 | At the geodetic station, 1° 10′.3, in September, and 1° 2′.0 in October, by two different instruments. |
| " | 1855.8 | Same station as in June, 1851. |
| 112 | 1855.6 | Near Magnetic Observatory, in the Smithsonian grounds. Affected by local attraction changing within the enclosure as much as 1½° Declination; on Capitol Hill, near Gilliss' station, by compass needle, 2° 25′. Ferruginous clay and sand overlying mica schist. |

| No. | Name of Station. | Latitude. | Longitude. | Declination West. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 113 | Davis, | 38 20.4 | 75 6.0 | 2 33.0 | 70 57.7 | 4.332 |
| 114 | Roslyn, | 37 14.4 | 77 23.6 | 0 26.5 | 69 17.3 | 4.614 |
| 115 | Stevenson's Point, | 36 6.3 | 76 10.7 | 1 39.6 | 68 54.5 | 4.660 |
| 116 | Shellbank, | 36 3.3 | 75 43.8 | 1 44.8 | 68 37.8 | 4.714 |
| 117 | Bodie's Island, | 35 47.5 | 75 31.6 | 1 13.4 | 68 18.1 | 4.755 |
| | | | | D. East. | | |
| 118 | Raleigh, | 35 46.8 | 78 37.8 | 0 44.5 | 68 11.6 | 4.943 |
| 119 | De Rosset, | 34 14.0 | 77 56.5 | 1 13.5 | 66 47.2 | 5.174 |
| 120 | Columbia, | 34 0.0 | 81 2.0 | 3 1.7 | 66 7.7 | 5.274 |
| 121 | Allston, | 33 21.7 | 79 12 3 | 2 6.5 | 65 29.5 | 5.402 |
| 122 | Macon, | 32 50.4 | 83 37.6 | 4 36.4 | 63 51.0 | 5.637 |
| 123 | Breach Inlet, | 32 46.3 | 79 48.7 | 2 16.5 | 64 31.9 | 5.457 |
| 124 | East Base, Edisto Island, | 32 33.3 | 80 10 0 | 2 53.6 | 64 4.1 | 5.532 |
| 125 | Savannah, | 32 5.0 | 81 5.2 | 3 40.3 | 63 40.0 | 5.600 |
| 126 | Tybee Island, | 32 1.5 | 80 50.6 | 3 32.1 | 63 38.4 | 5.584 |
| 127 | Cape Florida, | 25 40.4 | 80 9.8 | 4 25.2 | 56 13.0 | 6.615 |
| 128 | Sand Key, | 24 27.2 | 81 52.7 | 5 28.8 | 54 25.8 | 6.758 |
| 129 | Depot Key, | 29 7.5 | 83 2.8 | 5 20.5 | 59 55.3 | 6.140 |
| 130 | St. Mark's Light, | 30 4.5 | 84 12.5 | 5 29.2 | | |
| 131 | Dog Island, | 29 47.1 | 84 36.0 | 5 51.2 | | |
| 132 | St. George's Island, | 29 37.4 | 85 1.1 | 6 2.1 | | |
| 133 | Cape St. Blas, | 29 39.6 | 85 23.9 | 6 6.5 | | |
| 134 | Hurricane Island, | 30 4.4 | 85 40.3 | 6 12.2 | | |
| 135 | Fort Morgan, | 30 13.9 | 88 0.3 | 7 4.1 | | 6.218 |
| 136 | East Pascagoula, | 30 20.7 | 88 31.8 | 7 12.6 | 60 27.2 | 6.220 |
| " | " " | " " | " " | 7 8.9 | | 6.174 |
| 137 | Montgomery, | 32 22.0 | 86 18.0 | 5 18.3 | 63 5.4 | 5.850 |
| 138 | Fort Livingston, | 29 16.7 | 89 48.5 | 7 38.4 | | |
| 139 | Isle Dernière, | 29 2.0 | 90 54.3 | 8 19.2 | | |
| 140 | Dollar Point, | 29 26.0 | 94 52.6 | 8 57.4 | 57 53.3 | 6.541 |
| 141 | East Base, | 29 12.9 | 94 55.4 | 9 5.0 | 57 42.1 | 6.491 |
| 142 | Jupiter, | 28 54.8 | 95 20.1 | 9 8.7 | 57 11.7 | 6.582 |
| 143 | Rio Grande, | 25 57.4 | 97 7.6 | 9 0.9 | 52 23.6 | |
| 144 | San Diego, | 32 42.0 | 117 13.3 | 12 28.8 | | |
| " | " " | " " | " " | 12 31.7 | 57 38.6 | 6.271 |

| No. | Date. | Locality, Geology, and Remarks. |
|---|---|---|
| 113 | 1853.7 | On the west shore of Sinepuxent Bay, east of Berlin, Md. Ferruginous clay, and sand. |
| 114 | 1852.6 | Near Petersburg, Va. Drift, ferruginous clay. |
| 115 | 1847.1 | Western Point, at the mouth of Little River, Albemarle Sound, N. C. Tertiary clay and sand. |
| 116 | 1847.3 | On Albemarle Sound, east point of entrance into Currituck Sound. Alluvial mud, sand, and shells. |
| 117 | 1846.9 | North Carolina, near the beach, about 5 miles N. N. W. of the Light-House. White sand. |
| 118 | 1854.0 | North Carolina. Station 105 feet east, and 26 feet north of centre of Capitol dome. Granite rock underlying the soil. |
| 119 | 1854.4 | On a lot adjoining Dr. Drane's residence, north side of Market Street, Wilmington, N. C. Tertiary clay, gravel, and sand. |
| 120 | 1854.2 | South Carolina. In the Capitol Square, near the southwestern corner. |
| 121 | 1853.9 | Near Georgetown, S. C. Alluvium. |
| 122 | 1855.0 | Georgia. |
| 123 | 1849.3 | On Sullivan's Island, Charleston entrance, South Carolina. White sand. |
| 124 | 1850.3 | Edisto Island, S. C. Tertiary formation, alluvial mud, clay, and sand. |
| 125 | 1852.3 | On Hutchinson's Island, in range of Exchange and Presbyterian Church steeples, near the second embankment from the river. Alluvium. |
| 126 | 1852.3 | Near the mouth of Savannah River on a sand dune, near the boat-house. |
| 127 | 1850.1 | On the inside beach of Key Biscayne, the Light-House bearing S. W. Black mud and white sand. |
| 128 | 1849.6 | Near Key West, Florida. A small island on Florida Reef, composed of detritus of marine shells and coral. |
| 129 | 1852.2 | Cedar Keys, Fla., on the highest point of the island. Drifted white sand on alluvial mud. |
| 130 | 1852.3 | In the salt marsh, about 400 yards north of the Light. |
| 131 | 1853.3 | Apalachicola entrance (eastern). White sea-sand. |
| 132 | 1853.3 | Near Cape St. George, west entrance to Apalachicola Bay, Fla. White sea-sand. |
| 133 | 1854.1 | Florida. White sea-sand. |
| 134 | 1854.1 | St. Andrew's Bay, Fla. White sea-sand. |
| 135 | 1847.4 | 400 yards N. E. of the N. W. bastion of Ft. Morgan, Mobile Pt., Ala. Drifted white sand. |
| 136 | 1847.5 | Mississippi. About 1 mile east of the mouth of Pascagoula River, in the village near the shore. Tertiary formation, ferruginous clay and white sand. Dip observed in 1848. |
| " | 1855.1 | |
| 137 | 1855.3 | Near N. E. corner of Capitol Square. Deep red clay. |
| 138 | 1853.0 | Barataria Bay, La. Alluvium covered with drifted white sand. |
| 139 | 1853.1 | Caillou Bay, La. Alluvium covered with drifted white sand. |
| 140 | 1848.3 | On Galveston Bay, 10 miles N. W. of Galveston, Texas. Sandy loam. |
| 141 | 1853.2 | On Galveston Island, 10 miles S. W. of Galveston, and half a mile from the Gulf shore. Sandy loam. |
| 142 | 1853.4 | Four miles S. W. of Quintana, Texas, near the beach. Drifted sand. |
| 143 | 1853.9 | Near the mouth, on the American side. Alluvium. |
| 144 | 1851.3 | California, at the Plaza, near the "quarters." Very coarse sandstone. The high ridge of Point Loma is to the west. |
| " | 1853.8 | At the Plaza, near the Custom-House. |

| No. | Name of Station. | Latitude. | Longitude. | Declination East. | Dip. | Horizontal Intensity. |
|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | |
| 145 | San Pedro, | 33 46.0 | 118 16.0 | 13 30.5 | 59 32.6 | 6.144 |
| 146 | Point Conception, | 34 26.9 | 120 25.6 | 13 50.2 | | |
| 147 | San Luis Obispo, | 35 10.6 | 120 43.5 | 14 16.9 | 59 42.2 | 6.002 |
| 148 | Point Pinos, | 36 38.0 | 121 54.4 | 14 58.3 | | |
| 149 | San Francisco, | 37 47.6 | 122 26.8 | 15 26.9 | | |
| 150 | Bucksport, | 40 46.6 | 124 10.7 | 17 6.5 | | |
| 151 | Humboldt, | 40 44.7 | 124 11.0 | 17 4.5 | | |
| 152 | Ewing Harbor, | 42 44.4 | 124 28.8 | 18 29.7 | | |
| 153 | Cape Disappointment, | 46 16.6 | 124 2.0 | 20 19.1 | | |
| 154 | " " | " " | " " | 20 45.3 | | |
| 155 | Scarborough Harbor, | 48 21.8 | 124 37.2 | 21 29.9 | | |
| 156 | Waddah Island, Neé-ah Bay. | 48 22.0 | 124 36.6 | 21 46.9 | 71 7.0 | 4.276 |

| No. | Date. | Locality, Geology, and Remarks. |
|---|---|---|
| 145 | 1853.9 | On the open plain, about 3 miles north of San Pedro. Gravel resting on beds of recent fossil shells. |
| 146 | 1850.7 | Near the mouth of the valley of El Coxo. A rich soil; surrounding hills show limestone, quartz, &c. |
| 147 | 1854.1 | The surrounding hills are of soft limestone, resting on coarse, red sandstone, bearing enormous fossil remains, probably of tertiary age. |
| 148 | 1851.1 | Near Monterey, Cal. A rich soil, resting on sandstone. Beach formed of large granite boulders. |
| 149 | 1852.2 | Near the Presidio. Surrounding hills limestone. |
| 150 | 1853.6 | On the beach; sand and marsh. |
| 151 | 1854.3 | At the foot of the western part of the Bluff, composed of ferruginous clay and sand, resting on gravel, bearing fossil remains of *Elephas primigenius*. |
| 152 | 1851.9 | Near Cape Orford, Oregon. Geology very varied. South of Port Orford, coal and plumbago. North, limestone filled with fossil shells. |
| 153 | 1851.5 | On the beach; white sand, mixed with black ferruginous and auriferous sand. Surrounding hills basalt. |
| 154 | 1851.5 | On the summit of the Cape. Horizontal columnar basalt. |
| 155 | 1852.6 | Near Cape Flattery, Washington Territory. Sand, surrounding hills varied, limestone principally; basalt cropping out at Tootash Island. |
| 156 | 1855.6 | Near Cape Flattery, Washington Territory. Sandstone and shales of coal measures. |

## TABLE II.

*Magnetic Observations made on the Pacific Railroad Exploration, near the Parallel of 35°. By* LIEUTENANT J. C. IVES, *under the Direction of* CAPTAIN A. W. WHIPPLE, *U. S. Top. Engineers.*

| No. | Date. | Name of Place. | Latitude. | Longitude. | Elevation. | Declination. | Dip. | Total Intensity. Arb. Scale. |
|---|---|---|---|---|---|---|---|---|
| | | | ° ' | ° ' | Feet. | ° ' | ° ' | |
| 1 | Aug. 9, 1850, | Cambridge Observatory, | 42 23 | 71 7 | | W. 9 30 | 74 34 | 1.798 |
| 1 | May 10, 1854, | Cambridge Observatory, | 42 23 | 71 7 | | 9 46 | 74 33 | 1.798 |
| 2 | Oct. 17, 1853, | Albuquerque, | 35 6 | 106 38 | 5026 | E. 13 25 | 62 28 | 1.689 |
| 3 | Nov. 9, " | Isleta, | 34 54 | 106 40 | 4910 | 13 13 | 62 24 | 1.686 |
| 4 | " 12, " | Rio San José, | 35 1 | 107 14 | 5556 | 13 46 | 63 18 | 1.689 |
| 5 | " 14, " | Covèro, | 35 5 | 107 26 | 5880 | 13 49 | 62 26 | 1.689 |
| 6 | " 15, " | Hay Camp,* | 35 5 | 107 39 | 6081 | 35 56 | 35 39 | 1.566 |
| 7 | " 17, " | Aqua Fria, | 35 2 | 107 58 | 7757 | 13 25 | 62 5 | 1.687 |
| 8 | " 18, " | Prescription Rock,† | 35 3 | 107 14 | 7238 | 12 57 | 62 3 | 1.679 |
| 9 | " 22, " | Zuñi River, | 35 6 | 108 39 | 6336 | 13 24 | 62 2 | 1.683 |
| 10 | " 26, " | Arch Spring, | 35 5 | 108 48 | 6350 | | 61 55 | 1.682 |
| 11 | " 28, " | Cedar Forrest, | 35 1 | 108 55 | 6162 | 13 1 | 61 40 | 1.679 |
| 12 | " 29, " | Jacob's Well, | 35 4 | 109 14 | 5973 | 13 44 | 61 59 | 1.674 |
| 13 | " 30, " | Navajo Spring, | 35 6 | 109 20 | 5665 | 13 23 | 61 58 | 1.675 |
| 14 | Dec. 1, " | Carriso Creek, | 35 6 | 109 32 | 5550 | 13 54 | 62 5 | 1.673 |
| 15 | " 2, " | Near Lithodendron Creek, | 35 2 | 109 41 | 5500 | 13 33 | 61 57 | 1.667 |
| 16 | " 3, " | Near Rio Puerco of West, | 34 58 | 109 52 | 5110 | 14 0 | 61 46 | 1.668 |
| 17 | " 5, " | Color. Chiq., or Flax Riv., | 34 53 | 110 4 | 5015 | 13 42 | 62 15 | 1.670 |
| 18 | " 7, " | On Colorado Chiquito, | 35 0 | 110 25 | 4735 | 13 40 | 61 54 | 1.665 |
| 19 | " 8, " | " " " | 35 1 | 110 30 | 4760 | 13 21 | 61 41 | 1.663 |
| 20 | " 15, " | " " " | 35 5 | 110 33 | 4675 | | 61 44 | 1.662 |
| 21 | " 16, " | " " " | 35 12 | 110 37 | 4618 | 13 39 | 61 45 | 1.668 |
| 22 | " 17, " | " " " | 35 18 | 110 53 | 4594 | 13 42 | 61 55 | 1.667 |
| 23 | " 18, " | " " " | 35 21 | 110 56 | 4570 | | 62 3 | 1.678 |
| 24 | " 29, " | Saroux Spring, | 35 17 | 111 39 | 7378 | 13 52 | 61 33 | 1.659 |
| 25 | Jan. 9, 1854, | Cedar Creek, | 35 21 | 112 29 | 5672 | 13 49 | 62 6 | 1.674 |
| 26 | " 21, " | Pueblo Creek, | 34 56 | 112 46 | 5203 | 13 59 | 61 13 | 1.652 |
| 27 | " 23, " | Williams River,‡ | 34 59 | 112 57 | 5752 | 14 48 | 61 6 | 1.648 |
| 28 | " 28, " | " " | 35 7 | 113 13 | 4680 | 13 40 | 61 17 | 1.618 |
| 29 | " 30, " | Head of White Cliff Creek, | 35 12 | 113 21 | 4784 | | 61 14 | 1.659 |
| 30 | Feb. 1, " | White Cliff Creek, | 35 8 | 113 31 | 3526 | 14 42 | 60 48 | 1.648 |
| 31 | " 4, " | Big Horse Springs, | 35 1 | 113 36 | 2784 | 14 18 | 61 2 | 1.631 |
| 32 | " 8, " | | 34 36 | 113 28 | 1657 | 14 02 | 60 36 | 1.622 |
| 33 | " 9, " | Williams River, | 34 32 | 113 28 | 1500 | 13 58 | 60 44 | 1.627 |
| 34 | " 13, " | " " | 34 17 | 113 26 | 1015 | 13 24 | 60 14 | 1.631 |
| 35 | " 15, " | " " | 34 13 | 113 33 | 899 | 13 41 | 60 8 | 1.629 |
| 36 | " 16, " | | 34 14 | 113 39 | 868 | | 60 10 | 1.624 |
| 37 | " 20, " | | 34 17 | 113 56 | 441 | | 60 11 | 1.623 |
| 38 | " 21, " | On Colorado River, | 34 23 | 114 6 | 382 | 14 8 | 60 34 | 1.626 |
| 39 | " 22, " | | 34 27 | 114 11 | 416 | | 60 35 | 1.628 |
| 40 | " 23, " | | 34 36 | 114 16 | 590 | 13 51 | 60 30 | 1.627 |
| 41 | " 25, " | | 34 46 | 114 23 | 432 | 13 36 | 60 48 | 1.629 |
| 42 | Mar. 1, " | | 34 52 | 114 32 | 430 | 13 56 | 60 57 | 1.635 |
| 43 | " 3, " | Pai-ute Creek, | 35 6 | 114 54 | 2790 | 14 17 | 61 10 | 1.635 |
| 44 | " 6, " | Near Marl Springs, | 35 11 | 115 33 | 3793 | 13 59 | 60 56 | 1.627 |
| 45 | " 7, " | Sand Camp, | 35 6 | 115 46 | 2038 | | 60 49 | 1.632 |
| 46 | " 8, " | Soda Lake, | 35 3 | 115 59 | 1002 | 13 51 | 61 7 | 1.633 |

* This camp was upon the south side of the stream of lava which threads the valley of the Rio San José.

† This station was under the northern bluff of El Moro.

‡ Much lava in the vicinity of this station.

## TABLE III.

*Magnetic Observations from various Sources, not heretofore published, and collected for this Discussion.*

| Name of Place. | Latitude. | Longitude. | Declination. | Date. | Authority. |
|---|---|---|---|---|---|
| | ° ′ | ° ′ | ° ′ | | |
| Heiner's Run, N. Br. Susq., Pa., | 41 20 | 77 50 | 3 19 W. | 1856 | S. Tyndale. |
| Kelly's Island, west end L. Erie, | 41 36 | 82 43 | 2 13 E. | 1846 | Maps of Lake Surveys by U.S. Top. Engineers. |
| East Sister Island, " " " | 41 49 | 82 51 | 2 18 " | 1847 | |
| West Sister " " " " | 41 44 | 83 6 | 2 20 " | " | |
| Stony Point, " " " | 41 56 | 83 15 | 2 7 " | 1848 | |
| Waugoshance Pt., Mackinac Str., | 45 45 | 84 56 | 2 13 " | 1853 | |
| East of Duncan City, " " | 45 36 | 84 7 | 1 53 " | 1851 | |
| Near Newport, Franklin Co., Mo., | 38 30 | 91 10 | 9 21.6 " | 1839 | Dr. Goebel. |
| " " " " | " " | " " | 9 5.4 " | 1849 | " " |
| Fort Union, | 48 0 | 103 59 | 16 48 " | 1853 | Gov. I. I. Stevens. |
| Fort Benton, | 47 52 | 110 36 | 19 0 " | " | Northern Pacific Railroad Explorations. |
| Fort Owen, | 46 31 | 113 58 | 19 25 " | " | |
| Fort Wallawalla, | 46 4 | 118 48 | 19 40 " | " | |
| Panama, New Grenada, | 8 57 | 79 29 | 6 54.6 " | 1849 | Mex. Boun. Sur. |

## TABLE IV.

*Residual Differences between the Coast Survey Observations, reduced to* 1850, *and the Values obtained from the Accompanying Maps.*

The sign + or — shows how the residual is to be applied to the observed value to give that on the map.

| No. | Station. | Declination. | | Dip. | | Horizontal Intensity. | |
|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | | |
| 1 | Mount Harris, | +14 6 | — 6 | 76 2 | + 4 | 3.28 | — .04 |
| 2 | Ragged Mountain, | 13 54 | — 27 | 75 32 | + 13 | 3.37 | — .06 |
| 3 | Camden Village, | 13 36 | — 8 | 75 32 | + 12 | 3.37 | — .05 |
| 4 | Mount Sebattis, | 12 35 | — 6 | 75 35 | + 8 | 3.43 | — .09 |
| 5 | Mount Pleasant, | 14 24 | —2 48 | 75 59 | — 20 | 3.22 | + .15 |
| 6 | Cape Small, | 11 57 | + 19 | 74 58 | + 32 | 3.40 | — .01 |
| 7 | Mount Independence, | 11 45 | — 3 | 75 24 | + 3 | 3.36 | + .05 |
| 8 | Burlington, | 9 29 | + 1 | 75 44 | + 10 | 3.46 | — .11 |
| 9 | Bowdoin Hill, | 11 32 | + 9 | 75 11 | + 10 | 3.46 | — .03 |
| 10 | Richmond Island, | 12 15 | — 40 | 75 7 | + 8 | 3.46 | — .01 |
| 11 | Fletcher's Neck, | 11 14 | + 10 | 75 17 | + 1 | 3.44 | + .02 |
| 12 | Kennebunk Port, | 11 15 | — 6 | 75 11 | — 2 | 3.46 | + .02 |
| 13 | Mount Agamenticus, | 10 21 | + 30 | 74 57 | + 6 | 3.45 | + .05 |
| 14 | Cape Neddick, | 11 0 | — 1 | 74 55 | + 8 | 3.53 | — .03 |
| 15 | Patuccawa, | 10 45 | — 27 | 76 50 | —1 50 | 3.02 | + .51 |
| 16 | Kittery Point, | 10 27 | + 15 | 74 56 | + 4 | 3.50 | + .02 |
| 17 | Mount Unkonoonuc, | 9 10 | + 37 | 75 10 | — 19 | 3.47 | + .09 |
| 18 | Isle of Shoals, | 10 15 | + 26 | 74 46 | + 8 | 3.47 | + .07 |
| 19 | Plum Island, | 10 2 | + 19 | 74 53 | — 8 | 3.53 | + .04 |
| 20 | Annis Squam, | 11 39 | —1 21 | | | | |
| 21 | Beacon Hill, | 11 23 | —1 5 | 74 27 | + 9 | 3.62 | — .02 |
| 22 | Baker's Island Light, | 12 18 | —2 18 | 74 19 | + 14 | 3.69 | — .08 |
| 23 | Fort Lee, | 10 16 | — 16 | | | | |
| " | " " | 10 21 | — 21 | 75 26 | — 53 | 3.53 | + .08 |
| 24 | Coddon's Hill, | 11 51 | —1 48 | | | | |
| 25 | Little Nahant, | 9 43 | + 8 | 74 30 | — 3 | 3.55 | + .09 |
| 26 | Dorchester Heights, | 9 48 | — 9 | 74 16 | + 5 | 3.58 | + .07 |
| " | " " | 9 45 | — 6 | 74 18 | — 3 | 3.57 | + .08 |
| 27 | Nantasket, | 9 49 | — 4 | 74 18 | + 2 | 3.56 | + .09 |
| 28 | Blue Hill, | 9 35 | — 5 | 75 10 | — 52 | 3.50 | + .17 |
| 29 | Beacon Pole Hill, | 9 53 | — 50 | 74 27 | — 18 | | |
| 30 | Manomet Hill, | 9 38 | + 10 | 74 34 | — 27 | 3.62 | + .09 |
| | | | | 74 4 | + 3 | | |
| 31 | Copecut Hill, | 9 35 | — 29 | 74 14 | — 20 | | |
| 32 | Spencer's Hill, | 9 32 | — 41 | 75 13 | —1 20 | | |
| 33 | Shootflying Hill, | 9 58 | — 16 | 74 28 | — 34 | 3.64 | + .10 |
| " | " " | 9 57 | — 15 | 74 0 | — 6 | 3.65 | + .09 |
| 34 | Hyannis, | 9 39 | + 4 | 73 51 | 0 | 3.67 | + .07 |
| 35 | Fairhaven, | 9 15 | — 9 | 74 44 | — 55 | 3.57 | + .19 |
| 36 | Tarpaulin Cove, | 9 17 | — 17 | 73 53 | — 10 | 3.68 | + .10 |
| 37 | Indian Hill, | 9 6 | + 7 | 73 46 | — 5 | 3.71 | + .08 |
| " | " " | 9 6 | + 7 | 73 32 | + 9 | 3.71 | + .08 |
| 38 | Sampson's Hill, | 9 6 | + 15 | 73 28 | + 11 | 3.74 | + .05 |
| 39 | Nantucket, | 9 31 | + 2 | 73 49 | — 12 | 3.64 | + .14 |
| " | " | 9 31 | + 2 | 73 49 | — 12 | 3.66 | + .16 |
| 40 | MacSparran's Hill, | 9 16 | — 25 | 73 53 | — 10 | | |
| 41 | Point Judith Light, | 9 11 | — 41 | 73 47 | — 10 | 3.78 | + .02 |
| 42 | Providence, | 9 2 | — 5 | 74 5 | — 2 | 3.63 | + .11 |
| 43 | Watch Hill, | 7 45 | + 30 | | | | |
| 44 | Stonington, | 8 0 | + 9 | 73 30 | + 8 | | |

| No. | Station. | Declination. | | Dip. | | Horizontal Intensity. | |
|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | | |
| 45 | Groton Point, | +7 51 | + 10 | | | | |
| 46 | Saybrook, | 7 12 | + 30 | 74 40 | —1 9 | | |
| 47 | Greenport, | 7 37 | — 4 | 73 2 | + 22 | | |
| 48 | Sachem's Head, | 6 37 | + 44 | | | | |
| 49 | Fort Wooster, | 7 39 | — 30 | 74 19 | — 49 | 3.66 | + .21 |
| " | " " | 7 32 | — 23 | 74 14 | — 44 | 3.60 | + .27 |
| 50 | Oyster Point, | 6 38 | + 28 | 73 34 | — 4 | 3.76 | + .11 |
| " | " " | 6 35 | + 31 | 73 33 | — 3 | 3.73 | + .14 |
| 51 | New Haven, | 6 42 | + 27 | 73 33 | — 2 | 3.78 | + .08 |
| 52 | Milford, | 7 0 | + 3 | | | | |
| 53 | Bridgeport, | 6 41 | + 10 | 73 26 | — 2 | | |
| 54 | Black Rock, | 7 15 | — 33 | | | | |
| 55 | Norwalk, | 7 16 | — 43 | 73 11 | + 6 | | |
| 56 | Stamford, | 7 2 | — 41 | 73 8 | + 11 | 3.86 | + .06 |
| 57 | Saw-Pits, | 6 24 | — 12 | 72 59 | + 15 | | |
| 58 | Drowned Meadow, | 6 25 | + 23 | | | | |
| 59 | Lloyd's Harbor, | 6 38 | — 14 | 72 56 | + 16 | 3.84 | + .10 |
| 60 | Oyster Bay, | 7 17 | —1 2 | 73 4 | + 3 | 3.87 | + .08 |
| 61 | New Rochelle, | 5 56 | + 1 | 72 49 | + 18 | 3.82 | + .14 |
| 62 | Sands' Point, | 7 36 | —1 33 | | | | |
| " | " " | 6 21 | — 18 | | | | |
| 63 | Legget, | 5 52 | — 7 | 72 55 | + 10 | 3.97 | .00 |
| 64 | Greenbush, | 7 26 | — 2 | 74 59 | — 26 | 3.63 | + .03 |
| 65 | Cold Spring, | 5 5 | +1 10 | 73 43 | — 5 | 3.83 | + .03 |
| 66 | Bloomingdale Asylum, | 5 28 | + 20 | 72 43 | + 25 | 4.00 | — .02 |
| 67 | Columbia College, N. Y., | 6 40 | —1 11 | 72 43 | + 14 | | |
| " | " " | 6 47 | —1 4 | | | | |
| 68 | Governor's Island, | 6 11 | — 38 | 72 35 | + 20 | 3.97 | + .03 |
| 69 | Bedloe's Island, | 6 34 | —1 4 | 72 48 | + 6 | 3.96 | + .05 |
| 70 | Receiving Reservoir, | 6 0 | — 15 | 72 33 | — 31 | 3.98 | — .04 |
| 71 | Newark, | 5 53 | — 20 | 72 56 | — 4 | 3.95 | + .03 |
| 72 | Mount Prospect, | 6 13 | — 31 | 72 31 | + 29 | 4.04 | — .06 |
| 73 | Cole, | 5 55 | — 34 | 72 38 | + 9 | 4.02 | + .01 |
| 74 | Sandy Hook, | 6 13 | — 43 | 72 43 | + 2 | 4.05 | + .01 |
| " | " " | 5 43 | + 13 | 72 41 | + 4 | 3.96 | + .08 |
| 75 | Mount Rose, | 5 19 | — 31 | 72 37 | — 0 | 4.15 | — .09 |
| 76 | White Hill, | 4 44 | — 5 | 72 7 | + 17 | 4.14 | — .04 |
| 77 | Vanuxem, | 4 45 | — 15 | 72 26 | + 2 | 4.06 | + .05 |
| 78 | Girard College, | 4 9 | — 0 | 72 5 | + 11 | 4.13 | + .01 |
| " | " " | 4 3 | + 6 | 72 6 | + 10 | 4.27 | — .13 |
| 79 | Yard, | 6 18 | —2 21 | 72 52 | — 36 | 3.91 | + .23 |
| 80 | Chew, | 4 3 | | 72 18 | — 11 | 4.09 | + .07 |
| 81 | Tucker's Island, | 4 43 | — 4 | | | | |
| 82 | Tuckerton, | | | 72 26 | — 26 | | |
| 83 | Wilmington, | 2 49 | + 50 | 71 29 | + 35 | 4.22 | — .04 |
| 84 | Sawyer, | 3 6 | + 33 | 72 1 | — 1 | 4.16 | + .03 |
| 85 | Church Landing, | 6 7 | —2 25 | 71 26 | + 31 | 4.30 | — .10 |
| 86 | Fort Delaware, | 3 35 | — 2 | 71 38 | + 14 | 4.22 | — .01 |
| 87 | Hawkins, | 3 16 | + 26 | 71 46 | — 1 | 4.21 | + .02 |
| 88 | Pine Mount, | 3 32 | + 7 | 71 45 | — 1 | 4.23 | + .01 |
| 89 | Bombay Hook Light, | 3 36 | — 6 | 71 43 | — 3 | 4.19 | + .06 |
| 90 | Port Norris, | 3 22 | + 29 | 71 43 | — 6 | 4.20 | + .05 |
| 91 | Egg Island Light, | 3 20 | + 22 | 71 49 | — 17 | 4.20 | + .06 |
| 92 | Town Bank, | 3 16 | + 29 | 71 27 | — 8 | 4.26 | + .03 |
| 93 | Cape May Light (old), | 3 23 | + 19 | 71 29 | — 7 | 4.24 | + .06 |
| " | " " " (new), | 3 17 | + 25 | 71 23 | — 1 | 4.22 | + .08 |
| 94 | Lewes's Landing, | 3 1 | + 23 | | | | |

| No. | Station. | Declination. | | Dip. | | Horizontal Intensity. | |
|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | | |
| 95 | Pilot Town, | +3 0 | + 27 | 71 22 | — 11 | 4.28 | + .06 |
| 96 | Osborne's Ruin, | 2 55 | — 4 | 71 52 | — 10 | 4.12 | + .13 |
| 97 | Susquehanna Light, | 2 26 | + 37 | 71 55 | — 7 | 4.08 | + .16 |
| 98 | Finlay, | 2 37 | — 4 | 71 57 | — 19 | 4.04 | + .22 |
| " | " | 2 37 | — 4 | 71 49 | — 1 | 4.16 | + .10 |
| 99 | Pool's Island, | 2 42 | + 3 | 71 55 | — 18 | 4.11 | + .17 |
| 100 | Rosanne, | 2 34 | — 13 | 72 11 | — 37 | 4.03 | + .26 |
| 101 | Fort McHenry, | 2 32 | — 2 | | | | |
| 102 | North Point, | 1 57 | + 43 | 71 33 | — 4 | 4.17 | + .13 |
| " | " " | 1 53 | + 40 | | | | |
| 103 | Bodkin Light, | 2 19 | + 14 | 71 46 | — 17 | 4.18 | + .12 |
| 104 | Kent Island, (1) | 2 33 | + 6 | 71 17 | + 5 | 4.21 | + .11 |
| 105 | South Base, Kent Island, | 2 47 | — 20 | 71 41 | — 29 | 4.19 | + .16 |
| 106 | Taylor, | 2 37 | — 13 | 71 45 | — 26 | 4.21 | + .12 |
| " | " | 2 31 | — 17 | 71 22 | — 3 | 4.21 | + .12 |
| 107 | Marriott, | 2 27 | — 15 | 71 14 | — 5 | 4.25 | + .11 |
| " | " | 2 7 | + 15 | 71 13 | — 4 | 4.23 | + .13 |
| 108 | Webb's Hill, | 2 3 | + 15 | 71 22 | + 2 | 4.29 | + .03 |
| 109 | Soper's Hill, | 2 4 | — 1 | 71 55 | — 31 | 4.14 | + .19 |
| 110 | Hill's Hill, | 2 15 | — 15 | 71 11 | + 1 | 4.31 | + .05 |
| 111 | Causten's Hill, | 1 4 | + 44 | 71 16 | — 4 | 4.23 | + .13 |
| " | " " | 38 | +1 10 | 71 19 | — 7 | 4.28 | + .08 |
| " | " " | 37 | +1 11 | | | | |
| 112 | Washington City, | 5 38 | —3 47 | 71 16 | — 6 | 4.38 | — .01 |
| 113 | Davis, | 2 14 | +1 1 | 70 50 | — 2 | 4.35 | + .06 |
| 114 | Roslyn, | 13 | + 32 | 69 12 | + 21 | 4.64 | + .02 |
| 115 | Stevenson's Point, | 1 53 | — 44 | 68 58 | — 22 | 4.65 | + .14 |
| 116 | Shellbank, | 1 57 | — 27 | 68 40 | — 4 | 4.70 | + .09 |
| 117 | Bodies Island, | +1 27 | + 3 | 68 21 | + 3 | 4.74 | + .08 |
| 118 | Raleigh, N. C., | —1 3 | + 11 | 68 4 | — 7 | 4.97 | — .03 |
| 119 | De Rosset, | 1 30 | + 27 | 66 38 | — 6 | 5.20 | — .04 |
| 120 | Columbia, S. C., | 3 18 | + 12 | 66 0 | — 9 | 5.30 | |
| 121 | Allston, | 2 22 | + 10 | 65 22 | + 7 | 5.43 | — .08 |
| 122 | Macon, Ga., | 4 30 | + 30 | 63 41 | + 28 | 5.67 | + .01 |
| 123 | Breach Inlet, | 2 14 | — 34 | 64 32 | + 14 | 5.46 | |
| 124 | East Base, Edisto Island, | 2 54 | — 9 | 64 4 | + 23 | 5.53 | |
| 125 | Savannah, | 3 49 | + 10 | 63 35 | + 13 | 5.62 | |
| 126 | Tybee Island, | 3 41 | + 8 | 63 34 | + 14 | 5.60 | + .03 |
| 127 | Cape Florida, | 4 25 | — 8 | 56 13 | + 8 | 6.61 | — .09 |
| 128 | Sand Key, | 5 29 | + 5 | 54 26 | + 1 | 6.76 | + .07 |
| 129 | Depot Key, | 5 22 | + 12 | 59 55 | + 8 | 6.15 | + .04 |
| 130 | St. Mark's Light, | 5 31 | + 1 | | | | |
| 131 | Dog Island, | 5 53 | + 10 | | | | |
| 132 | St. George's Island, | 6 4 | + 10 | | | | |
| 133 | Cape St. Blas, | 6 8 | + 4 | | | | |
| 134 | Hurricane Island, | 6 14 | + 6 | | | | |
| 135 | Fort Morgan, | 7 3 | — 1 | | | 6.21 | |
| 136 | East Pascagoula, | 7 12 | 0 | 60 30 | — 3 | 6.20 | |
| " | " " | 7 12 | 0 | | | 6.20 | |
| 137 | Montgomery, | 5 6 | —1 4 | 62 52 | + 20 | 5.89 | — .10 |
| 138 | Fort Livingston, Belle Isle, | 7 40 | — 4 | | | | |
| 139 | Isle Dernière, | 8 20 | + 17 | | | | |
| 140 | Dollar Point, | 8 57 | — 7 | 57 53 | + 7 | 6.53 | — .04 |
| 141 | East Base, | 9 7 | — 4 | 57 42 | 3 | 6.52 | + .02 |
| 142 | Jupiter, | 9 10 | — 5 | 57 12 | 6 | 6.59 | |
| 143 | Rio Grande, | —9 2 | — 5 | 52 23 | 7 | | |

| No. | Station. | Declination. | | Dip. | | Horizontal Intensity. | |
|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | ° ′ | ° ′ | | |
| 144 | San Diego, | —12 28 | — 21 | | | | |
| " | " " | 12 32 | — 25 | 57 38 | + 33 | 6.30 | — .04 |
| 145 | San Pedro, | 13 37 | + 18 | 59 32 | — 17 | 6.17 | — .01 |
| 146 | Point Conception, | 13 50 | + 5 | | | | |
| 147 | San Luis Obispo, | 14 13 | + 6 | 59 42 | + 45 | 6.03 | — .03 |
| 148 | Point Pinos, | 14 57 | — 0 | | | | |
| 149 | San Francisco, | 15 25 | — 10 | | | | |
| 150 | Bucksport, | 17 3 | — 14 | | | | |
| 151 | Humboldt, | 17 0 | — 16 | | | | |
| 152 | Ewing Harbor, | 18 28 | + 6 | | | | |
| 153 | Cape Disappointment, | 20 19 | + 22 | | | | |
| 154 | " " | 20 45 | — 4 | | | | |
| 155 | Scarborough Harbor, | 21 27 | — 7 | | | | |
| 156 | Waddah Isl. (Neé-ah Bay), | —21 41 | + 8 | 71 7 | | 4.32 | .00 |

## V. METEOROLOGY.

### 1. On the Spirality of Motion in Whirlwinds and Tornadoes. By W. C. Redfield, of New York.

1. An aggregated spiral movement, around a smaller axial space, constitutes the essential portion of whirlwinds and tornadoes.

2. The course of the spiral rotation, whether to the right or left, is one and the same in this respect, throughout the entire whirling body, so long as its integrity is preserved. But the oblique inclination which the spiral movement also has to the plane of the horizon, is in opposite directions as regards the exterior and interior portions of the revolving mass. Thus, in the more outward portion of the whirlwind, the tendency of this movement is obliquely downward, when the axis is vertical; but in the interior portion, the inclination or tendency of the spiral movement is upward. This fact explains the ascensive effects which are observed in tornadoes and in more diminutive whirlwinds.

3. Owing to the increased pressure of the circumjacent air, in approaching the earth's surface, the normal course of the gradually descending movement in a symmetric whirlwind is that of an invo-

luted or closing spiral; while the course of the interior *ascending* movement of rotation is that of an evolved or opening spiral. Hence, the horizontal areas of the higher portions of the whirl exceed greatly those of its lower portions.

4. The area of the ascending spiral movement in the vortex, as it leaves the earth's surface, is by far the smallest portion of the whirling body; for the reason that the rotation here is proportionally more active and intense, being impelled by the aggregated pressure and momentum of the more outward portion of the whirlwind as it converges from its larger areas, on all sides, by increasingly rapid motion, into the smaller areas of ascending rotation.* That this interior portion of the whirl resembles an inverted hollow cone, or column, with quiescent and more rarefied air at its absolute centre, may be inferred from the observations which have been made in the axial portions of the great cyclones. Into this axial area of the tornado the bodies forced upward by the vortex cannot fall, but are discharged outwardly from the ascending whirl. The columnar profile of this axial area sometimes becomes visible, as in the water-spouts, so called.

5. Accessions caused by circumjacent contact and pressure are constantly accruing to the whirling body, so long as its rotative energy is maintained. A correlative diffusion from its ascending portion must necessarily take place, towards its upper horizon; and this is often manifested by the great extent or accumulation of cloud which results in this manner from the action of the tornado. In other words, there is a constant discharge from the whirling body in the direction of least resistance.

6. The spirality of the rotation, and its inclination to the horizon, in

* The law of increment in the velocity of the whirlwind, as it gradually converges into lesser areas by its spiral involution, is that which pertains to all bodies when revolving around interior foci towards which they are being gradually drawn or pressed nearer and nearer, in their involute course; the line of focal or centripetal pressure thus sweeping *equal areas in equal times*, at whatever diminution of distance from the centre; except as the velocity may be affected in degree by the resistance of other bodies. Such resistance is of little effect in a tornado, because its revolving mass is mainly above all ordinary obstacles, such as orchards and forests, into which the spirally *descending* and accelerated blast, near the contracted extremity of the inverted and truncated cone of the whirl, penetrates with constant freshness and intensity of force, already acquired in the higher and unobstructed region.

the great portion of the whirl which is exterior to its ascending area, are not ordinarily subject to direct observation. Nor is the outline or body of the more outward portion of the whirlwind at all visible, otherwise than in its effects.

7. In *aqueous* vortices, the axial spiralities of the exterior and interior portions of the whirl are in reverse direction to those in the atmosphere, the descending spiral being nearest to the axis of the vortex. Hence, lighter bodies, and even bubbles of air, are often forced downward in the water, in the manner in which heavier bodies are forced upward in the atmosphere.

The foregoing is simply a statement of results which I have derived from a long course of observation and inquiry. It does not include the partial and imperfect exhibitions of whirlwind action, which often occur, nor the various movements and phenomena which are collaterally associated with tornadoes and whirlwinds, some of which are of much significance.

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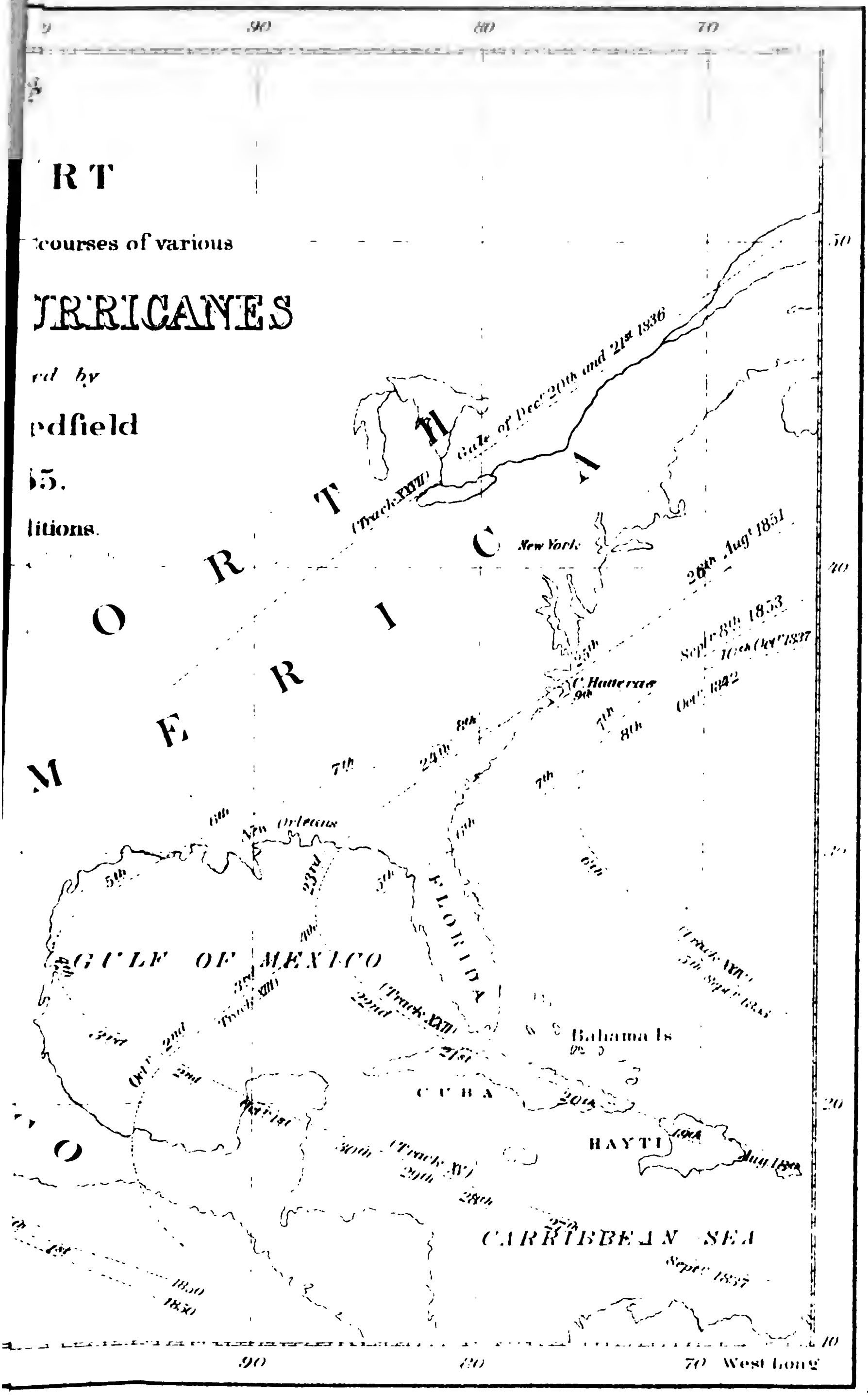
## 2. On Various Cyclones or Typhoons of the North Pacific Ocean; with a Chart, showing their Courses of Progression. By W. C. Redfield, of New York.

This memoir is founded to a considerable extent on data obtained from the log-books and meteorological reports of the ships composing the Expedition to Japan, under the command of Commodore Matthew C. Perry, and is intended for publication in the appendix to the official account of the Expedition.

Of the typhoon encountered by the United States ship Mississippi, on the 7th of October, 1854, on her return from Japan, some notice was given at the last meeting of the Association at Providence. Allusion was then made, also, to the great cyclone encountered by various ships of the squadron, in July, 1853, between the coasts of China and Japan, and at the Loo Choo Islands. This remarkable storm spread over a path of perhaps one thousand miles in breadth, while its rate of advance hardly exceeded three miles an hour.

The Chart then exhibited, on which were shown the courses of



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litions.
NORTH AMERICA
New York
C. Hatteras
New Orleans
FLORIDA
GULF OF MEXICO
Bahama Is
CUBA
HAYTI
CARRIBBEAN SEA
Gale of Dec. 20th and 21st 1836
(Track XXVII)
26th Aug. 1851
Sept. 8th 1853
10th Oct. 1837
Oct. 1842
(Track XIII)
(Track XXII)
(Track XV)
(Track XIV)
5th Sept. 1835
Sept. 1837
1850
90
80
70
70 West Long
50
40
30
20
10

several cyclones in the North Pacific, has been improved by various additions, and is now offered for publication. Some portions of the memoir, with several abbreviated reports of cyclones, are here submitted.

CYCLONES AND THE MONSOONS.—In the Asiatic seas, as elsewhere, the judgment of the navigator is often misguided by the loose and inaccurate statements which are found in various authorities. Thus, it is said that gales or hurricanes rarely occur in these seas, except at the change of the monsoons, or the period of the equinoxes. These assumed axioms are greatly erroneous; as the inspection of the storm charts will suffice to show.

The actual relations of the cyclones to the monsoons and local winds of the Asiatic seas are of much interest, and merit a careful examination. It is quite remarkable that the monsoons should be found to have little, if any, control or influence, as regards the regular courses and development of the cyclones. This may show the predominance of cosmical laws and influences over the apparently opposing conditions which are so extensively presented in these alternating winds.

The extent of the westerly monsoons, parallel to, and on both sides of, the equator, appears to be far greater than has been recognized by most writers. In the northern hemisphere, these counter winds of the true trades extend from the east coast of Africa, near longitude 45° E., at least to longitude 175° E., in the Central Pacific. The proper trade-wind appears to consist of a comparatively thin stratum of aerial current, moving upon the ocean surface, and distinguished by its inclination towards the equator. On this stratum is ordinarily imposed another current, probably of greater depth and volume, into which the trade-wind ultimately merges, and which also tends westward in the trade-wind latitudes, but generally inclines *from* the equator; as is shown by the rain-clouds and squalls which it carries, and by the direction of translation imparted to the cyclones which it embodies. This important wind-current, so little recognized by most writers, frequently alternates with or displaces the true trades, and it displaces still more frequently the westerly monsoon, as a surface wind; especially to the east of Sumatra. Thus, the "southwest monsoon" of the China Sea and the Western Pacific, which extends to the shores of Japan, is very often displaced from the surface by the subsidence

of the main current of southeasterly wind; more especially in the regions near the Asiatic coast.

UNIVERSALITY OF THE LAW OF STORMS. — The law of rotation and progression in storms, as developed on the Atlantic Ocean, which was substantially discerned by the present writer in the year 1821, is essentially cosmical or world-wide in its origin and application. This soon became apparent, in examining the accounts of gales which are found in the voyages of Cook, Vancouver, and others, in the several oceans and climatory zones of our globe. Hence, the polar relations of the phenomena presented are necessarily changed in the southern hemisphere, where, in all our relative comparisons, south must be substituted for north; east and west remaining the same.

This similarity of polar relations in the winds of the two hemispheres, and the corresponding influences on the barometer which are shown by the opposite cyclonic changes of these winds, are virtually recognized in Captain P. P. King's account of his surveying expedition in the southern hemisphere, about the year 1826, as is seen in his sailing directions. The more complete and satisfactory evidence of this cosmical system, or law, of cyclonic action, which is derived from a series of extensive geographical observations, made in the paths of storms in the southern hemisphere, has since been furnished in the several works of Reid, Thom, and Piddington. The latter author has also investigated many storms of the Sea of Bengal and the Indian Ocean, and has noticed various gales or typhoons of the China Sea. Some of the following notices may serve to increase our knowledge of Asiatic storms.

CHINA SEA AND GULF OF TONQUIN. — On the southern coast of China, the semiannual changes of the monsoons are found to occur in April, and about the end of September. On former occasions I have published notices of some of the numerous typhoons which cross the China Sea, more commonly from May to October, on routes corresponding in direction to those of the hurricanes in the West Indies, and with like characteristics. That observant old voyager, Dampier, states that on the coast of Tonquin the typhoons are expected in the months of July, August, and September. He says, that in these typhoons "the wind comes on fierce, and blows very violent at north-

east, twelve hours, more or less. When the wind begins to abate, it dies away suddenly, and falling flat calm, it continues so an hour, more or less; when the wind comes about to the southwest, and it blows and rains as fierce from thence as it did before from the northeast, and as long." A better description of a violent cyclone, as observed on its centre-path in the lower latitudes, and before its recurvation, could hardly be given.

A Typhoon in February, in the Trade-Winds of the Pacific. — At noon of February 3d, 1853, the Annie Buckman, sailing for Canton, was in latitude 12° 30′ N., longitude 129° 16′ E., with barometer at 29.75, and a double-reefed topsail breeze from northeast. Between this time and the 9th the vessel was subject to a very violent typhoon; during which both the direction of the wind and the course of the vessel went round the compass, by the north, west, and south, to the northeast quarter, on the 9th. At noon of this day the vessel was in latitude 18° 9′ N., longitude 127° 25′ E., barometer 29.80, and of the few entries given, the lowest was 29.25, at 4 P. M. of February 7th; wind then from the westward, and increasing soon after to its greatest violence. Captain Barber states that in twenty years of navigation, in all oceans, he had not encountered ahurricane so violent.

Bonin Islands. — On the 25th of October, 1853, the United States ship Plymouth encountered a typhoon at Port Lloyd, in latitude 27° 5′ N., longitude 142° 11′ E., which commenced with squalls of wind from east-southeast, under which the barometer began to fall. "At 9 P. M. it fell calm, and continued so for little less than an hour, when the wind came out again suddenly from northwest, with terrific violence, blowing, if anything, still harder than from east-southeast. Barometer when lowest, 28.97; at which it arrived very rapidly; and when it commenced rising, it did so in the same manner." This cyclone evidently completed its recurvation while passing over the Bonin Islands.

On the 28th of October, 1854, another severe typhoon passed over Port Lloyd, where the United States ship Vincennes, of the surveying expedition, was then lying at anchor. In its recurvation, its centre went round to the westward of Port Lloyd, as indicated by the suc-

cessive phases of the wind and barometer. It has been ably described by John Rodgers, Esq., commander of the expedition, and Anton Schönborn, assistant astronomer, in a communication addressed to the present writer.

Reindeer's Cyclone, July, 1850. — The American ship Reindeer was dismasted in a furious hurricane on the 19th of July, 1850, in latitude 18° 30′ N., longitude 139° E.; about twelve hundred miles from the coast of China. She ran with bare poles, under the easterly winds of the cyclone; thus nearing its vortex, till the barometer had fallen to 28.85, when the wind veered to south-southeast, in a perfect blast; the ship broached to, and the masts soon went overboard.

With the knowledge of storms we now possess, our ships ought not to be thus disabled in open sea.

The Freak's Typhoon of May 1, 1850. — The English brig Freak fell in with this cyclone in latitude 19° 28′ N., longitude 138° 44′ E., with the wind east by south, varying to east by north, and the brig ran westward with an increasing gale. At midnight the master began to suspect that he was approaching the vortex of a cyclone that was travelling to the northwest, and at 1 A. M., May 2d, he hove to on the starboard tack, to allow it to pass him. It continued blowing a hurricane, and at noon the wind became east-northeast, with the barometer at 29.22. Between 2 and 3 P. M., the foretopmast was broken off by the force of the wind, which at this time was beyond description. At 3.50 P. M., the barometer had fallen to 28.87, its lowest point. The wind from noon continued to haul northward, its greatest strength being from about northeast by north, and the master thus found, to his surprise, that he was in the northwest quadrant of the cyclone, and on the left side of its centre path; it having already recurved to the northward and eastward. From 4 P. M., the barometer began to rise, and the force of the gale to decrease.

The easterly winds of this cyclone having veered by the north, the master's inference that the recurvation in its course took place during the time his vessel was in the gale, appears correct; the centre of the vortex having recurved southward and eastward of the vessel's place. His full account may be seen in the London Nautical Magazine, 1851, pp. 273-275.

Ladrone or Marian Islands.—These islands lie near longitude 146° E., and are subject to hurricanes, for which the inhabitants prepare, by lashing down and securing their houses. They are expected in the months of June, July, and August; also, in December and January. The island of Guam, latitude 13° 26′ N., was visited on the 23d of September, 1855, by a typhoon of the most violent character. More than eight thousand persons were left without a house or roof to protect them from the fury of the storm.

Cyclone of the J. N. Gosler, May, 1855.—The American ship J. N. Gosler, from San Francisco for Hong Kong, experienced a heavy typhoon on the 28th of May, 1855, in latitude 16° 40′ N., longitude 147° 45′ E.; nearly two thousand miles from the Chinese coast. She carried away sails, spars, &c., and was abandoned on the 30th, with nine feet of water in the hold. The officers and crew succeeded in reaching the Marian Islands, in their boats.

Strong's Island and Ascension.—Mr. John T. Gulick, of the Sandwich Islands, in the year 1852, visited several of the Micronesian Islands, near the equator, in company with the missionaries who then settled at these islands. At Strong's Island (Nalan), in latitude 5° 12′ N., longitude 163° E., they were informed by King George, the principal chief, that some years previous the island had been visited by a hurricane which wholly destroyed the bread-fruit trees, and caused a famine which nearly depopulated the island. He described it as blowing first from one quarter of the heavens and then from another. At Ascension Island (Bonabe), which is about three hundred miles distant in a west-northwest direction, a similar account was received.

Cyclone of the Austerlitz, November, 1851.—The new clipper Witchcraft arrived at Hong Kong on the 3d of December, from California, with loss of mainmast-head and all the topmasts. She experienced a typhoon on the 13–14th of November, in latitude 22° 40′ N., longitude 150° E.

About the same period, in latitude 19° 48′ N., longitude 159° E., the American ship Austerlitz was totally dismasted. The chain-plates were torn from her sides, and her hull otherwise much injured, and the vessel was soon after abandoned.

It cannot be doubted that the Austerlitz and Witchcraft fell, successively, into the heart of this cyclone. We have thus two points established in its track, which are distant from each other about five hundred and thirty nautical miles. These positions show its course to have been north 71° west, or west-northwest, nearly. The position of the Austerlitz is more than two thousand five hundred miles from Hong Kong, and is somewhat less from the Sandwich Islands.

Kingsmill Islands and Gilbert Archipelago. — These islands, situated on and near the equator, near longitude 175° E., were visited by a ship of the United States Exploring Expedition under Captain Wilkes. Variable winds from the northward and westward prevail from October to April; and they have violent gales from the southwest. According to Kirby, who was taken off the islands, these storms are typhoon-like, and last three or four days. The westerly sides of the islands receive most damage, and both land and trees are swept away.

Radack Islands. — These islands are scattered between 6° and 11° north latitude, and longitude 168° to 173° E. Captain Kotzebec ascertained that hurricanes of great violence sometimes occur in September and October, and the natives always anticipate with dread the recurrence of those months.

The Japan's Typhoon. — In December, 1832, the Japan, a new ship, encountered a severe hurricane in latitude 13° N., longitude about 160° W. This position is nearly on the meridian of the most western of the Sandwich Islands.

The Sandwich Islands. — At the Sandwich Islands, latitude 19° to 22° N., longitude 155° to 160° W., the cyclones which occur are not commonly of great severity, although the native huts are sometimes unroofed or destroyed. The *kona*, or southerly wind, by which the trade-wind, during part of the year, is much interrupted, may be referred, at least in part, to those cyclones which find their centre-path northward of the islands, or which complete their recurvation in that region. The easterly gales, which accord nearly with the trade-wind in their direction, indicate an axis-path which lies southward of the islands. The actual presence or influence of a cyclone may commonly be determined by the oscillations of the barometer.

The absence of intense violence in any of the cyclones which visit this group may possibly be due to their geographical position. But it is equally probable that this qualified exemption may result from a diversion of the course of the central vortex of the cyclone, occasioned by the great height and compact form of Hawaii, the most southeastern of these islands. For the group lies in almost a direct line, which is parallel to the ordinary course of cyclones in the lower latitudes, being, from the summit of Mauna Kea to the centre of Kauai, north 61° west. A cyclonic vortex, if moving previously on this line, would be displaced by the eastern angle of Hawaii; which island has an area of nearly four thousand square miles; a portion of which rises far above the upper horizon of the cyclones, and at two points reaches an elevation of nearly fourteen thousand feet. The protection, or partial diversion of course thus occasioned, must extend to the high but smaller islands which lie to the leeward in the same track.

Cyclone of the Lark. — The Lark, an American barque from Canton for Valparaiso, met a severe gale on the 23d of September, 1843, in latitude 15° N., longitude 138° 40′ W. The Lark also encountered a violent typhoon at an earlier date, when off the island of Formosa.

Cyclones of the Eastern Pacific. — For the sake of brevity, I pass over several accounts of violent cyclones which have been found between the Sandwich Islands and the Southern coasts of Mexico and Central America. The occurrence of hurricanes in this part of the Pacific is by no means unfrequent; and the cases I have quoted are instructive to navigators. The omitted notices are contained in the appendix to the account of the Japan Expedition, already referred to. The sketches of storm-tracks, as first intimated, are found on the small chart of the North Pacific, hereto appended.

If these imperfect notices shall contribute in any degree to the safety and success of our ships and commerce, it will be a grateful reward for the attention and labor which this important subject has at any time required.

New York, *September 6th*, 1856.

3. ON THE AVOIDANCE OF THE VIOLENT PORTIONS OF CYCLONES, WITH NOTICES OF A TYPHOON AT THE BONIN ISLANDS. By JOHN RODGERS, Commander, U. S. N., and ANTON SCHÖNBORN, Assistant Astronomer. (In the form of Letters to W. C. Redfield, by whom they were communicated to the Association.)

COMMANDER RODGERS'S LETTER.

I AM a firm believer, out of my own experience, in the truth of your theory of hurricanes. I think you have enabled me to avoid storms, into whose centres I should have been unwilling to be involved, and I feel, therefore, that I am under personal obligations to you for your happy meteorological discoveries. You have conferred by them a great good to the nation and to the world.

I do not know whether my notes of weather have any value in regard to the hurricane experienced by the Mississippi, on October 7th, 1854. On September 23d, preceding this typhoon, we were in the China Sea, in latitude 21° 44′ N., longitude 119° 17′ E. The weather was very threatening. We were standing to the southward, and a black cloud was ahead of us, with vivid lightning, with a cross and violent sea, with heavy rain, and fitful squalls continually increasing in frequency and force. I considered that I saw a cyclone before us, and that we should avoid its force, by sailing away from it. We stood to the northward. The barometer soon rose, and the wind moderated.

At the Bonin Islands, on October 28th, 1854, we had a typhoon. The harbor of Port Lloyd is formed by the crater of an extinct volcano. The sides rise precipitately above the water to the height of some twelve hundred feet. You will easily perceive, then, that the anchorage must be in a great degree protected from the violence of the wind. Yet it blew awfully. It stripped all the leaves from the trees, all vegetation was blighted, and even the sweet-potato vines in the sheltered valleys were destroyed by it. As I could not at first believe that the wind had destroyed them, I attributed their wilting and turning black to some unseen electrical agency. I afterwards concluded that the wind had twisted and torn their sap-vessels, so as to destroy their vitality.

This storm was not so marked as to give any distinct warning of its

approach. The evening before the hurricane, the surf broke more heavily upon the mouth of the harbor than I had seen it. Had we been at sea, I have little doubt but that we should have known of its approach. This storm is well described in the accompanying paper by Mr. Schönborn, assistant astronomer on board.

We had a gale on November 9th, 1854, in latitude 18° 22′ N., longitude 143° 45′ E., which I thought was the edge of a typhoon. We ran on until I had satisfied myself as to its character, and then we hove the ship to on the starboard tack, heading away from it. We soon raised the barometer and improved the weather. This case is also described in the accompanying paper of Mr. Schönborn.

In the steamer John Hancock, which I commanded, we were, on May 20th, 1854, upon the verge of a typhoon. The weather was not violent, but the seas were peculiar, rising up into sharp cones, and running in every direction. They buffeted the vessel in every part, — striking her upon the lee bow and weather quarter at once. I remarked to the officers on board, that I felt sure we were upon the edge of a typhoon. It gave me, however, no uneasiness. I concluded that we were behind it, and that keeping the vessel away would increase our distance from it.

We steered off once, in a fresh squall, for about fifteen minutes, and then hauled up to our course again. We ran on with a fair wind. I expressed a wish to know how any vessel some one or two hundred miles to the northward and eastward of us was faring.

This curiosity was satisfied by the accompanying extract from the log-book of the British ship, Harkura. She was a large Indiaman, well out of the water, and in appearance such a strong, wholesome vessel as a seaman would select to stand heavy weather.*

Typhoons are rare in the China seas in the month of May. This is therefore not without interest.

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* The ship Harkura left Hong Kong for London, May 16th, 1854, and returned to port, under jury masts, on the 11th of June. She had fine weather till the 18th, on which day boarded the Dutch barque Johan Paul, then just escaped from pirates. On the 19th, wind fresh and steady at east and east-northeast. On the afternoon of 20th [*nautical time*] moderate winds from east-northeast, the barometer falling in the evening, with lightning to the southward. Latitude at noon of that day, 16° 22′ N., longitude 113° E. At 10 P. M., a heavy bank rising in the southeast, with lightning and distant thunder, close-reefed the topsails and stowed the mainsail,

## ANTON SCHÖNBORN'S LETTER.

DURING the past five days the weather had been rather warm, but very fine. Light winds from southeast were prevailing, which kept

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spanker, and jib. At midnight, barometer still falling, took in mizzen-topsail and foresail, and at 2 A. M. stowed main-topsail. Not much wind, but sea getting cross and high. At 5 A. M., strong winds and heavy rain, barometer fallen three tenths since the preceding noon. Sent down all top hamper, and secured all sails with extra gaskets. At 10 A. M. [Saturday, 20th] gale increased to a hurricane, with a fearful cross, high sea. Stowed fore-topsail and topmast-staysail, and brought the ship to on port tack, got a sail in mizzen-rigging to keep ship to the wind, then so violent that no sail could stand it. At noon [commencement of 21st, nautical time] latitude, by account, 15° N., longitude 112° 20′ E.

The afternoon commenced with a severe gale, speedily increasing to a perfect hurricane; barometer down to 28.50. At 2 P. M. ship lying with her lee yard-arms in the water, and barometer still falling rapidly. Fearing the ship would founder, cut away fore and mizzen-topmasts; but that being insufficient to right the vessel, cut away the fore-topmast. The vessel then righted a little, the wind still blowing with fearful violence, and increasing. The main-topmast went over the side, taking with it the head of the mainmast.

Immediately after this it fell a flat calm; the barometer down to 27.70. Got the wreck of main-topmast cut away from alongside, as well as that of the foremast, which hung to windward. At 3 P. M., the wind blew to the northwest, veering to west and southwest, blowing with tenfold violence. The lee bulwarks all gone, with everything movable about the deck, the sea up to the combings of the main hatch. The starboard side of forecastle washed out, and also starboard poop cabin. At 3 45 P. M., ship righting a little, rigged two pumps and pumped her dry. At 6 P. M., the fury of the typhoon moderated, and the barometer commenced rising. Gale continued at southwest, veering round to south. Commenced rigging jury-masts. May 22d [nautical time], latitude 15° N., longitude 112° 10′ E. At 8 P. M. [21st, true time] weather moderated. Sea going down and barometer rising. Wind south and southeast.—*Extracted from Hong Kong Gazette, June 14th, 1854.*

CAPTAIN CROWE'S REMARKS ON THE ABOVE TYPHOON.—The evening of Friday, May 19th, the weather looked very threatening, but nothing gave reason for suspecting the vicinity of a typhoon. [?] The clouds had a dirty, red appearance; but the quickly repeated flashes of lightning and the distant moaning of the thunder in the southeast quarter were portentous of an approaching gale. The barometer did not give early indications of what was coming, [?] only three tenths of fall appearing up to the time of the commencement of the gale. The fall then, however, was very rapid, and in all of twenty years' experience (eleven in command) I never saw the mercury so low in the tube by an inch. During the lull, when we were in

the temperature of the air, even in the night, above 80°, yet in the warmest hours of the day it would seldom be over 85° in the shade. This morning, before sunrise, light squalls from southeast, accompanied by drizzling rain, interrupted for the first time the continued fine weather we had experienced. At noon the wind changed to the north of east, the rain ceased, it began to clear up, and I could see the blue

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the vortex, the barometer, a standard one, by Shephard of London, stood at 27.50; afterwards, when we were engaged about the wreck of the masts, it was reported to me as standing at 27 inches; in fact, altogether out of sight. The wind commenced at east-northeast; stood in that quarter 24 hours (moderate in early part), veered to northeast, whence it continued steady till we cut away the masts; then it suddenly subsided into a calm, which continued for half an hour; then, without a moment's warning, it opened out in the northwest in a most frightful tornado, so violent that words cannot express its force, and so continued for an hour, when it veered to west, and gradually afterwards to southwest and south, with continued violence. Rain throughout very heavy. Had not the vessel been brought to on the port tack, as Horsburgh directs, when the wind shifted after the lull, the vessel must certainly have gone down stern foremost; as it was, the gust taking her over the stern, she came up to the wind, and so lay in safety during the remainder of the cyclone.

[*Note.* — The interests of navigation require it to be stated, that on the evening before the disaster Captain Crowe had, in the falling state of the barometer, and the direction of the wind, sufficient evidence to show that *near by, in the southeast, was a typhoon, then crossing his path.* Had he wore ship at this time, or even brought to on the starboard tack, till the wind should have veered eastward and the barometer commenced rising, he would have sustained no damage. But in maintaining his course under the unchanging northeasterly wind, and falling barometer, he pushed directly into the heart of the cyclone; as has too often been done by others.

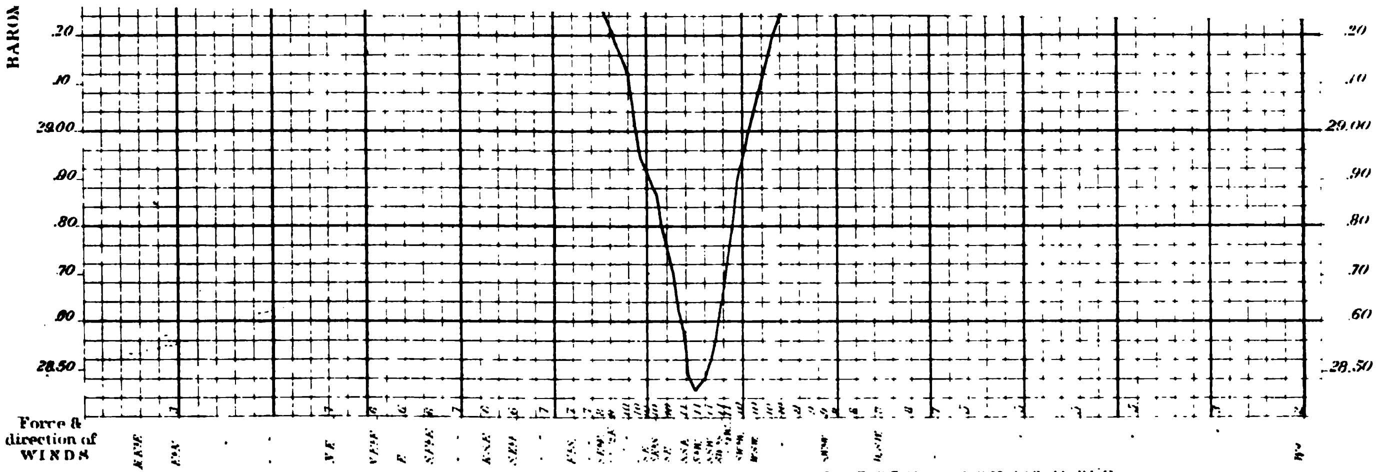
Commander Rodgers was fortunate in falling behind the violent portion of this terrific cyclone, and was thus able to escape its force without changing his track. He appends the log-book records of the John Hancock, from which it appears that at 3 P. M. of May 20th the barometer had fallen to 29.60; the wind having veered by the northwest to west by north; its greatest force 6; the course of the vessel about north-northeast. Latitude at noon, 11° 55′ N., longitude 111° 17′ E. This corresponds to the Harkura's *nautical* date of 21st; her distance from the John Hancock then being 195 miles; the vortex at that time, somewhat nearer. From 3 to 6 P. M. the barometer rose but little. Later in that day the wind was west by south, and then variable, the barometer rising to 29.80. The 21st commenced with wind at south-southeast, which continued so till noon, in latitude 13° 51′ N., longitude 112° 47′ E. Course north by east. After noon, the wind varied from south-southeast to east, diminishing in force to 3. — W. C. R.]

sky at times between the slowly moving cumuli. In the afternoon, about 3 P. M., being on shore, I heard some peals of far-off thunder, seemingly to eastward; the same had been noticed on board ship. A range of mountains obstructed the sight to northeast, east, and southeast; in the latter direction I perceived the high, white tops of heavy clouds (cum. str.) some distance off. Occasional rain-squalls passed on both sides of us. In the evening the squalls were more frequent, it rained often and profusely; the sky became overcast and hung round with dark-looking clouds, especially to southwest, where we could see the horizon. At 8 P. M., barometer 29.859; sympiesometer 29.896; aneroid 29.822; temperature of air 81°.1; of water 78°.7; of rain-water 75°.2.* About 8 P. M., flashes of vivid lightning to east and northeast, and peals of heavy thunder, occurred, which were repeated several times until 10 P. M., at intervals, stronger or fainter.

*October 28th, 4 A. M.*—During the night the squalls came from northeast, and increased much in violence. About 4 A. M. the wind hauled to eastward and began to blow more steadily. The rain fell all night and morning very abundantly and in large drops. Barometer 29.654; sympiesometer 29.675; aneroid 29.630; temperature of air 80°.6; water 77°.6; rain-water 75°.7. Towards 6 A. M. the wind hauled to southeast by east, increasing; it lessened somewhat about 8 A. M., but regained soon its former strength from east by south. Rain now fell incessantly, but in smaller quantity. Temperature of rain-water 77°. The weather had a very dark and threatening appearance; a thick mist covered the horizon seawards; the surf broke high and violently on the reef near the entrance of the harbor, and on the rocks outside.

At 9 A. M., barometer 29.471; sympiesometer 29.465; aneroid 29.450; temperature of air 81°.1; water 77°.7; rain-water 77°; wind

* Mr. Schönborn appends an excellent diagram, showing the fall and rise of the barometer under the successive winds of this cyclone as it passed over the ship, as determined by frequent and careful observations. He adds also the curves indicating the movements of the sympiesometer and aneroid during the same period. It is a graphic exhibition of the cyclonic action, and affords a test of the relative value of the several instruments, under the successive phases of the storm. He adds two other diagrams of like character; one of which, together with that just noticed, I have reduced for these pages, so far as relates to the barometer. I regret that they could not be reproduced entire on this occasion. — W. C. R.




AT PORT LLOYD, BONIN ISLANDS. LAT 27 05 35 N. LON. 142 11 30 E.
Observed & drawn by Anton Schonborn (*Reduced by W.C.R.*)

southeast by east, force 7. After 10 A. M. the wind increased continually, shifting by degrees to southeast; the barometers and sympiesometers fell rapidly. A water-spout was observed at 11 A. M. in the mouth of the harbor moving quickly southwestward. It had nearly the height of the neighboring south bluff, behind which it disappeared. By going over the breakers, a great quantity of spray was carried away with it, whirling around the cylinder. The clouds were not defined except the scud, which flew swiftly at no great distance above us. Shortly before noon the weather became thicker; the surrounding hills appeared as indistinct shadows; indeed, we were sometimes so entirely enveloped in mist and fog, that we could not see a ship's length around us.

Noon, barometer 29.123; sympiesometer 28.956; aneroid 29.100; temperature of air 79°.8; water 77°.7; rain-water 75°.7; wind southeast one half east, 10. At 1.45 P. M. the wind had attained its greatest force, and blew with unabated fury until 3.30 P. M., veering in this time from southeast by south gradually to southwest one half west. There was no calm at the climax of the storm noticeable. The sympiesometer stood lowest at 2.20 P. M. (at 28.233, wind south by west), and the barometer and aneroid at 2.30 P. M. (at 28.443 and 28.482, wind south one half west).* All three instruments remained but a few minutes at their lowest position, and rose then as rapidly as they had fallen. It rained almost continually, rather lightly, but the drops fell with great violence, and made me at first believe them to be mixed with hailstones, which idea however I found contradicted by examination and by the temperature of the rain-water. As the wind turned to the westward of south, there came a heavy swell through the entrance of the harbor, which increased as the wind hauled more to the west. After 3.30 P. M. the force of the wind diminished slightly.

At 5 P. M., barometer 29.169; sympiesometer 29.060; aneroid

* The nearest approach of the axis or centre was indicated by these lowest observations. As the gradual veering of the wind was in accordance with the apparent course of the sun, and no lull or remission having occurred at the crisis of the gale, it is evident that the observers were to the right of the axis-path, which swept round to the southward and westward of Port Lloyd. At this time it had partially completed its recurvation, and the cyclone was entering upon its northeasterly progression. — W. C. R.

29.178; temperature of air 77°.7; water 77°.7; wind west by south one fourth south, 10. Towards sunset the weather moderated, the clouds assumed shapes again, and for a short time had a remarkably lurid appearance, the whole atmosphere, filled with vapor, seemed to be lighted up, and gave to the surrounding landscape a yellowish tinge.

At 8 P. M., barometer 29.533; sympiesometer 29.459; aneroid 29.529; temperature of air 77°.6; water 77°.7; wind southwest by west, 8. Fresh squalls of light rain from southwest by south, and west-southwest, passed frequently. The form of the clouds looked loose and jagged. Now and then the sky was partially clear overhead, and the stars were visible even through the thinner mist-like clouds.

*October 29th, 4 A. M.*—Barometer 29.748; sympiesometer 29.652; aneroid 29.744; temperature of air 78°; water 78°; wind west-southwest, 5. The weather has been improving much during the night. At 9 A. M., barometer 29.853; sympiesometer 29.830; aneroid 29.850; temperature of air 80°.8; wind light from the westward; weather very fine.

Very respectfully,

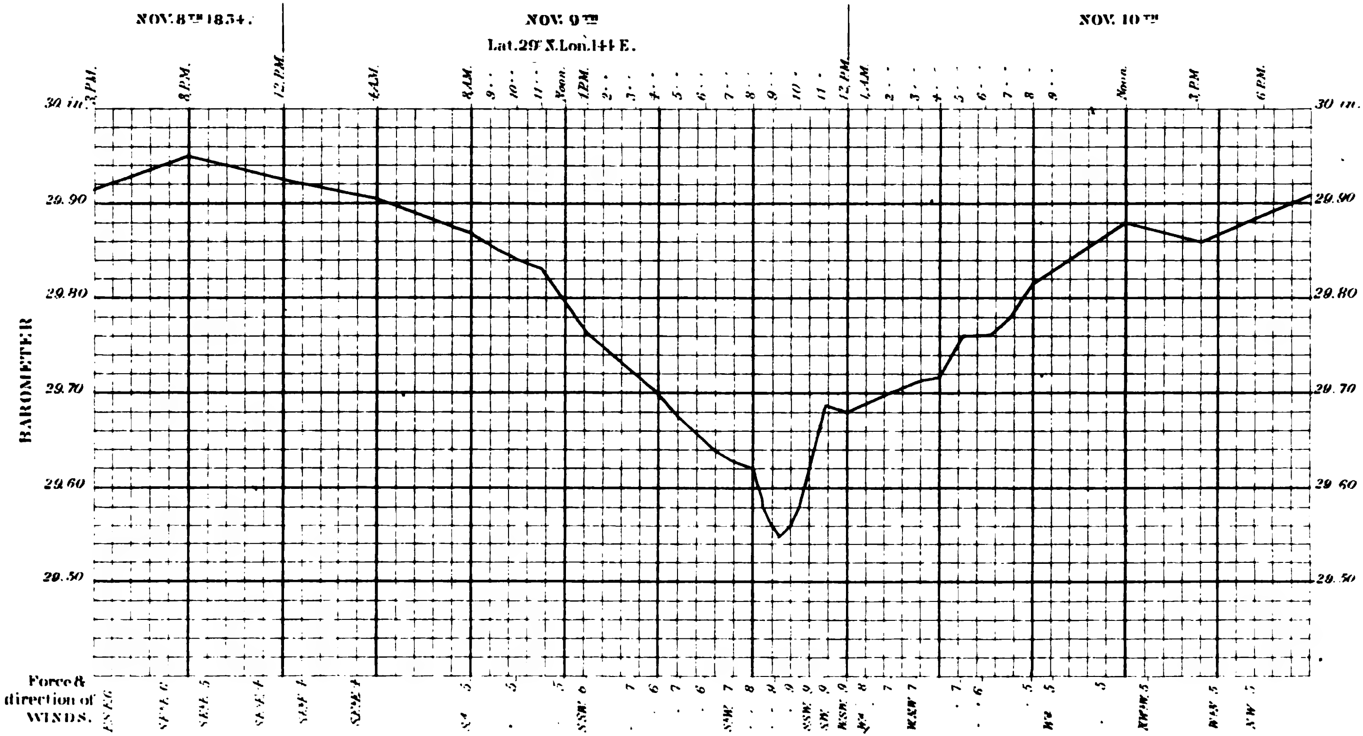
ANTON SCHÖNBORN,

*Assistant Astronomer.*

U. S. Ship Vincennes, November 9th, 1854.

DURING the day we had pleasant weather. A steady south wind blew all the morning, advancing us speedily on our way to the north. In the afternoon the wind freshened, hauling to south-southwest. The barometer and sympiesometer had been falling since 8 P. M. of the previous day, and stood at 3 P. M. at 29.717 and 29.710; temperature of air 18°.1; water 78°.4; wind south-southwest, 7. We were then in latitude 28° 43′ N., longitude 143° 59′ E.

Towards evening, when the sun neared the horizon, he glanced with unusual brightness through the clouds, and the sunset was magnificent. The gilded edges of the cumuli to northwest contrasted finely with the dark appearance of the cloud-bank which began to rise on the horizon. South and westward the upper and lower strata of clouds exhibited a great variety of colors, from pale yellow to brilliant purple, and some of them, which passed swiftly overhead,




VINCENNES RUNNING Nº E. UNTIL 8.20 P.M. NOV. 9th THEN HOVE TO WITH THE HEAD TO S.E., ON STARB. TACK.

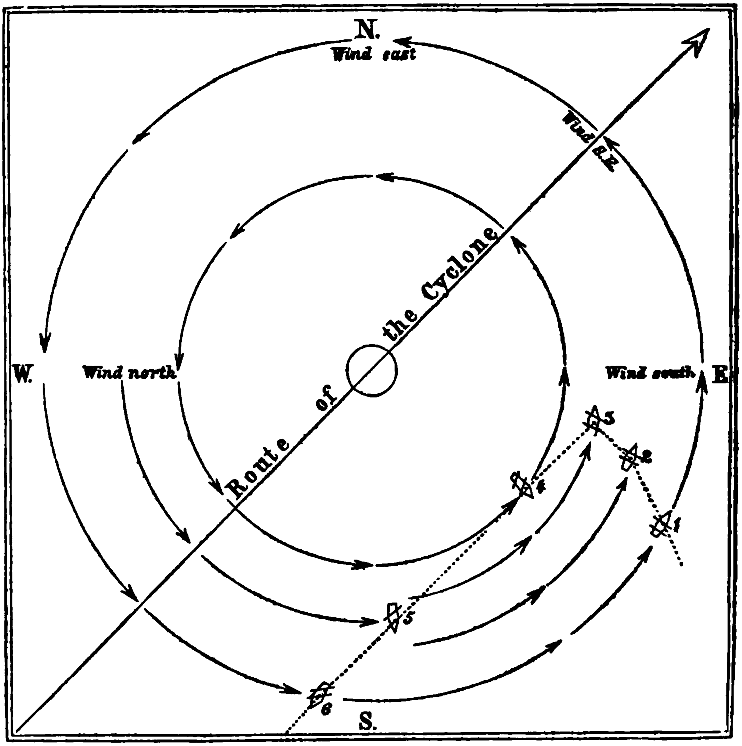
Observed & drawn by Anton Schonborn (Reduced by W.C.R.)

Lith. of Robertson & Seibert 93 Fulton St. N.Y.

were even of a greenish hue. A low, compressed mist, orange-colored, lay on the water to the west, serving as a line of demarcation between the calm and beautiful sky above and the already troubled sea below.

As the glow of the sunset lessened, the cloud-bank to the northwest began to rise, and when it became dark, flashes of vivid lightning followed each other in rapid succession, illuminating at times the whole northwestern part of the heavens. The wind veered back to south by west, increasing considerably in force, accompanied by sudden puffs. The waves became high and irregular, owing to a cross swell from south and northwest. A thick mist enveloped us sometimes so that only a small space overhead was clear. The barometer fell constantly. At 8 P. M. *the ship was hauled by the wind on the starboard tack, with the head to the eastward.* The barometer and sympiesometer stood lowest at 9.20 P. M. (29.548; 29.572). At this time also the wind was most vehement from south-southwest. The barometer began to rise after half past nine o'clock. Towards midnight the weather moderated slightly. The wind blew in gusts from the southwest, veering by degrees to westward, and some showers of rain fell. At 4 A. M., on the 10th, the force of the wind had greatly diminished, hauling to west-northwest, and the weather cleared up.

It is very probable that we were in the southeastern wing of the cyclone. From the collected facts the following diagram has been constructed. By the general appearance of the sky and the swell, which came at first from northwest, and afterwards from north, it seemed that the storm moved to northeast. We ran at first into it,— and by lying to, the storm left us, passing on its way to northeast. We entered the circle at No. 1, with a course of north-northeast, which was soon after changed to north by east; our position on the diagram, therefore, became successively that of No. 2 and No. 3.




Position No. 1, November 9th, 2 P. M. Wind south-southwest; ship's course north-northeast, which was changed at 4 P. M. to north by east.

No. 2, at 6.30 P. M. Wind south-southwest; ship's course north by east; cloud-bank to northwest (toward the centre of the storm).

No. 3, at 8.20 P. M. Wind south by west; ship's course north by east; after which the ship was hove to, head eastward.

No. 4, 9.20 P. M. Wind south-southwest; lowest barometer; strongest wind. (Nearest the centre.)

No. 5, November 10th, 1 A. M. Wind westward. Weather moderating.

No. 6, 3 A. M. Wind west-northwest.

4. Results of a Series of Meteorological Observations made at New York Academies from 1826 to 1850. By Franklin B. Hough, of Albany.

*Abstract.*

The recommendation of this Association in 1851* was successful in procuring from the New York Legislature an appropriation for publishing the results of a series of meteorological observations made at sundry Academies under the direction of the Regents of the University, at sixty-two academies, during a quarter of a century, and an aggregate period of 773 years. A reference of my paper of 1851† will give a synopsis of the kind and extent of the subjects of observation, and I will, on this occasion, limit myself to a concise statement of the leading results of the series under consideration.

From want of uniformity in the returns, the records of periodical phenomena could not be satisfactorily arranged for comparison; but it may be stated as a general rule, that the blossoming of plants and other harbingers of spring occur from two to three weeks earlier on Long Island than in the northern and western parts of the State, while in the latter the first frosts and snows indicating the approach of winter are seen nearly a month sooner. From rapid growth in the colder sections, the harvest of spring grain occurs at nearly the same time throughout the State.

The first appearance of birds of passage is much more uniform, the extreme intervals of the same species seldom exceeding a week.

The mean temperature for the whole time, at all the stations,‡ was 46°.74, distributed through the several months as follows: —

| Months. | First Half. | Second Half. | Whole Month. | Months. | First Half. | Second Half. | Whole Month. |
|---|---|---|---|---|---|---|---|
| | ° | ° | ° | | ° | ° | ° |
| January, | 25.17 | 24.19 | 24.68 | July, | 69.12 | 70.23 | 69.67 |
| February, | 21.68 | 26.59 | 24.11 | August, | 69.94 | 66.99 | 68.46 |
| March, | 31.02 | 35.86 | 33.44 | September, | 62.14 | 57.60 | 59.87 |
| April, | 43.05 | 47.58 | 45.30 | October, | 50.49 | 46.05 | 48.27 |
| May, | 53.37 | 59.06 | 56.21 | November, | 41.24 | 34.11 | 37.67 |
| June, | 63.72 | 67.49 | 65.60 | December, | 29.19 | 25.30 | 27.24 |

* See Proceedings of this Association, 1851, p. 397.

† Ibid., p. 168.

‡ Parts of years were uniformly omitted in the tabular summaries, as tending to produce unequal results.

The following table shows the names and location of stations at which observations were made, with their elevation above tide, number of years reported, and the extreme and mean temperature of each.

| Academies and their Location. | Elevation above Tide. | No. of Years Observed. | Thermometer. Mean Temperature. | Highest Degree. | Lowest Degree. | Extreme Range. | Mean Range. Monthly. | Mean Range. Annual. |
|---|---|---|---|---|---|---|---|---|
| | Feet. | | ° | ° | ° | ° | ° | ° |
| Albany, Albany Co., | 130 | 24 | 48.60 | 97 | —23 | 120 | 67.5 | 100 |
| Amenia Seminary, Dutchess Co., | 540 | 1 | 46.73 | 96 | —16 | 112 | 45.5 | 112 |
| Auburn, Cayuga Co., | 650 | 22 | 46.62 | 96 | —14 | 110 | 68 | 96 |
| Bridgewater, Oneida Co., | 1,286 | 4 | 42.66 | 94 | —31 | 125 | 70.5 | 112 |
| Buffalo, Erie Co., | 623 | 2 | 46.14 | 92 | —22 | 114 | 55.5 | 114 |
| Cambridge, Washington Co., | ? | 14 | 45.39 | 98 | —36 | 134 | 74.2 | 116 |
| Canajoharie, Montgomery Co., | 284 | 3 | 45.77 | 97 | —36 | 133 | 62 | 118 |
| Canandaigua, Ontario Co., | 707 | 10 | 45.73 | 94 | —11 | 105 | 62 | 96 |
| Cayuga (Aurora), Cayuga Co., | 447 | 13 | 49.16 | 96 | —10 | 106 | 63.2 | 94 |
| Cherry Valley, Otsego Co., | 1,335 | 15 | 44.27 | 98 | —30 | 128 | 73 | 105 |
| Clinton (East Hampton), Suffolk Co., | 16 | 17 | 48.74 | 95 | — 8 | 103 | 61.5 | 88 |
| Cortland (Homer), Cortland Co., | 1,096 | 18 | 44.67 | 95 | —28 | 123 | 71.5 | 105 |
| Delaware (Delhi), Delaware Co., | 1,384 | 2 | 46.66 | 93 | —17 | 110 | 59 | 110 |
| Dutchess (Poughkeepsie), Dutchess Co., | ? | 16 | 50.61 | 102 | —22 | 124 | 73 | 106 |
| Erasmus Hall (Flatbush), King's Co., | 40 | 24 | 51.62 | 96 | — 4 | 100 | 59.5 | 87 |
| Fairfield, Herkimer Co., | 1,185 | 19 | 43.26 | 96 | —26 | 122 | 72.3 | 105 |
| Farmers' Hall (Goshen), Orange Co., | 425 | 11 | 47.56 | 98 | —30 | 128 | 69.8 | 102 |
| Franklin (Malone), Franklin Co., | 703 | 3 | 43.54 | 94 | —24 | 118 | 65 | 109 |
| Franklin (Prattsburg), Steuben Co., | 1,494 | 10 | 49.43 | 100 | —19 | 119 | 71 | 106 |
| Fredonia, Chautauque Co., | 728 | 18 | 48.38 | 97 | —12 | 109 | 65.8 | 93 |
| Gaines, Orleans Co., | 426 | 4 | 46.71 | 94 | — 7 | 101 | 57.5 | 94 |
| Gouverneur, St. Lawrence Co., | 400 | 12 | 43.95 | 100 | —40 | 140 | 79.8 | 123 |
| Granville, Washington Co., | ? | 14 | 45.39 | 102 | —31 | 133 | 74.5 | 117 |
| Greenville, Greene Co., | ? | 1 | 48.05 | 91 | —17 | 108 | 51.5 | 108 |
| Hamilton, Madison Co., | 1,127 | 17 | 44.82 | 96 | —34 | 130 | 77.5 | 112 |
| Hartwick, Otsego Co., | 1,100 | 16 | 46.54 | 96 | —30 | 126 | 71 | 104 |
| Hudson, Columbia Co., | 150 | 17 | 47.84 | 99 | —24 | 123 | 67.8 | 102 |
| Ithaca, Tompkins Co., | 417 | 17 | 48.38 | 98 | —18 | 116 | 70.5 | 101 |
| Johnstown, Fulton Co., | 688 | 14 | 44.91 | 96 | —30 | 126 | 72.3 | 112 |
| Kinderhook, Columbia Co., | 126 | 17 | 47.00 | 102 | —30 | 134 | 74.5 | 109 |
| Kingston, Ulster Co., | 188 | 19 | 49.57 | 100 | —30 | 130 | 71 | 104 |
| Lansingburg, Rensselaer Co., | 30 | 20 | 47.92 | 101 | —28 | 129 | 74 | 114 |
| Lewiston, Niagara Co., | 280 | 17 | 47.88 | 97 | — 6 | 103 | 65.3 | 92 |
| Lowville, Lewis Co., | 800 | 19 | 43.62 | 100 | —40 | 140 | 79 | 120 |
| Mexico, Oswego Co., | 331 | 11 | 49.08 | 99 | —24 | 123 | 72 | 106 |
| Middlebury, Wyoming Co., | 800 | 19 | 46.78 | 100 | —20 | 120 | 78 | 103 |
| Millville, Orleans Co., | ? | 8 | 46.11 | 95 | —12 | 107 | 65 | 99 |
| Monroe (Henrietta), Monroe Co., | 600 | 3 | 45.84 | 96 | — 9 | 105 | 60 | 97 |
| Montgomery, Orange Co., | ? | 13 | 48.60 | 104 | —33 | 137 | 77.5 | 109 |
| Mount Pleasant, Westchester Co., | 125 | 12 | 47.41 | 97 | — 8 | 105 | 58.5 | 93 |
| Newburg, Orange Co., | 150 | 18 | 97.67 | 105 | —15 | 120 | 69 | 100 |
| New York Institute Deaf and Dumb, | 50 | 6 | 51.01 | 92 | — 2 | 94 | 49 | 84 |
| North Salem, Westchester Co., | 361 | 19 | 48.06 | 102 | —31 | 133 | 74 | 105 |
| Ogdensburg, St. Lawrence Co., | 280 | 1 | 43.48 | 92 | —10 | 102 | 44 | 102 |
| Oneida Conference Seminary (Cazenovia), Madison Co., | 260 | 19 | 43.65 | 97 | —28 | 125 | 74 | 109 |
| Oneida Institute (Whitesborough), Oneida Co., | 405 | 7 | 44 83 | 98 | —33 | 131 | 71.8 | 115 |
| Onondaga (Onondaga Hollow), Onondaga Co., | 600 | 16 | 47.18 | 99 | —22 | 121 | 72.8 | 106 |

| Academies and their Location. | Elevation above Tide. | No. of Years Observed. | Thermometer. Mean Temperature. | Highest Degree. | Lowest Degree. | Extreme Range. | M Range. Monthly. | Annual. |
|---|---|---|---|---|---|---|---|---|
| | Feet. | | ° | ° | ° | ° | ° | ° |
| Oxford, Chenango Co., | 961 | 16 | 44.74 | 98 | —36 | 134 | 76.3 | 114 |
| Oyster Bay, Queen's Co., | ? | 2 | 50.81 | 95 | — 3 | 92 | 48.2 | 90 |
| Palmyra, Wayne Co., | ? | 1 | 45.33 | 93 | — 9 | 102 | 54 | 102 |
| Plattsburg, Clinton Co., | 120 | 5 | 45.17 | 100 | —20 | 120 | 63 | 108 |
| Pompey, Onondaga Co., | 1,300 | 17 | 42.83 | 91 | —18 | 109 | 66 | 99 |
| Redhook, Dutchess Co., | ? | 12 | 48.36 | 98 | —28 | 126 | 68 | 102 |
| Rochester, Monroe Co., | 506 | 19 | 46.79 | 102 | — 9 | 111 | 67 | 95 |
| St. Lawrence (Potsdam), St. Lawrence Co., | 394 | 31 | 43.61 | 96 | —34 | 130 | 78.3 | 114 |
| Schenectady, Schenectady Co., | ? | 3 | 45.82 | 91 | —16 | 107 | 55.3 | 101 |
| Springville, Erie Co., | 1,082 | 7 | 45.32 | 95 | —20 | 115 | 69.2 | 102 |
| Syracuse, Onondaga Co., | 400 | 1 | 47.30 | 94 | — 3 | 97 | 45 | 97 |
| Union Hall (Jamaica), Queen's Co., | ? | 25 | 49.87 | 100 | — 7 | 107 | 64.2 | 92 |
| Union Literary Society (Bellville), Jefferson Co., | 400 | 9 | 45.51 | 98 | —35 | 133 | 74.5 | 112 |
| Utica, Oneida Co., | 471 | 22 | 45.38 | 97 | —27 | 124 | 75 | 104 |
| Washington (Salem), Washington Co., | ? | 10 | 46.53 | 100 | —40 | 140 | 73.8 | 119 |
| Mean, | | | 46.74 | | | | 67 | 103 |

A comparison of the temperature of the several months, at different stations, shows a greater uniformity throughout the State in summer than in winter, and consequently a more rapid transition of temperature in spring and autumn.

The station having the highest annual mean was at Erasmus Hall (Flatbush), and that having the greatest range was at Gouverneur. The extreme range becomes *less* as the mean becomes *higher*. The annual extremes of seventeen stations which were less than 100° had, with one exception, a mean above that of the State. The mean temperatures of the last half of April and October are nearly equal to that of the year.

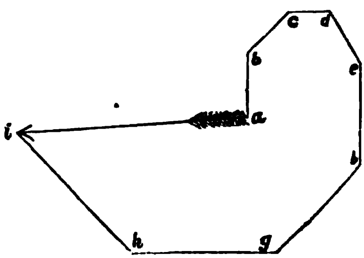
The well-known influence of elevation upon temperature is strikingly shown by comparing the observations of stations near each other, but of different altitudes. A reference to the foregoing table will show a difference between Onondaga and Pompey; Utica and Bridgewater or Fairfield; Poughkeepsie and Amenia; Newburg and Goshen, &c., which can be attributed to no other cause. An isothermal chart, constructed from the observed surface temperatures of places of different altitudes would therefore exhibit nodes and irregularities in its lines, due to inequalities of surface, which could not be understood without an accompanying section of the country, or some notation for indicating the relative altitude of different places.

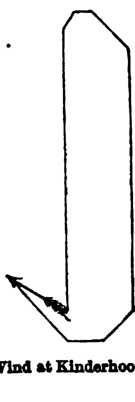
Other influences likewise tend to produce permanent deviations of temperature from that due to geographical position, such as prevailing winds from local peculiarities of surface, the vicinity of bodies of water, character of soil with reference to absorption and radiation of heat, &c. The experience of the series under consideration shows that too much care cannot be taken in observing and reporting the various local causes which tend to modify the results of meteorological records.

The mean direction of the winds for the whole State was S. 80° W. during thirty per cent of the time, the remainder being neutralized by opposite winds. At thirty-four stations the mean was south, and at twenty-eight, north, of the mean of the whole State. One of the most obvious peculiarities in the observation upon winds is the influence of local valleys in the vicinity of the stations. As with minor exceptions the prevailing course of the hills and valleys of New York is north and south, it is highly probable that the true prevailing course of aerial currents across the State is nearer west. A record of the direction of clouds would possess much more scientific value, and should always form a part of a well-conducted series of observations.

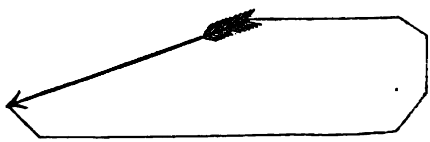
In the volume under consideration, diagrams were used to illustrate the effect of local causes upon winds, which at the same time indicated the comparative amount of the several winds.

If, in the annexed figure, the lines *ab*, *bc*, *cd*, *de*, *ef*, *fg*, *gh*, *hi*, represent in direction and length all the winds that blow from the several points in a given month, the arrow *ai*, will represent the resultant of the winds, and the sum of the broken lines *ab*, *bc*, &c., to *i*, the entire period of the month. It is evident that the prevalence of northerly and southerly winds, as at Kinderhook, would give the figure a vertical elongation and very much shorten



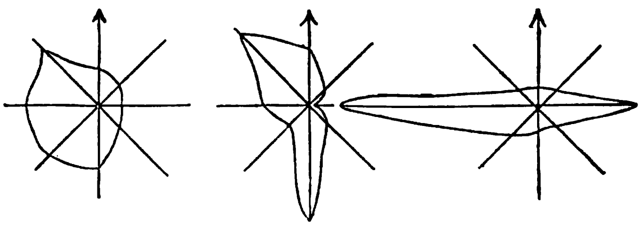



Wind at Kinderhook.



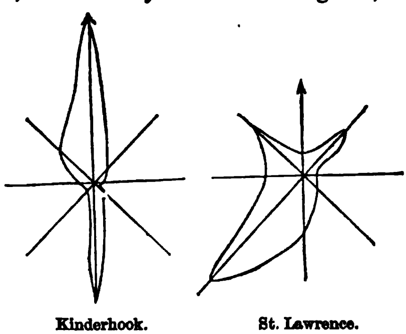
Winds at Utica.

the resultant, while at places situated like Utica, in an east and west valley, the elongation would be horizontal, and the resultant increased in quantity. The relative prevalence of winds may also be shown, and the modifying influences of local causes demonstrated, by laying off from a central point, in different directions, distances proportioned



Whole State. Albany. Utica.

to the prevalence of winds from the several points, and connecting the spaces thus laid off by a line, as shown by the annexed figures, in which the final results of the winds of the whole State, and of Albany, Utica, Kinderhook, and St. Lawrence are delineated. In general, the winds in the State, are more northerly in the first half of the year, and more southerly in the other half, than the annual average.



Kinderhook. St. Lawrence.

The aspect of sky as observed during a quarter of a century, indicates a prevalence of clear open clouds in the proportion of 15½ to 14¾, and a progressive increase of serene sky from December to July, from which it declines to December. No scale of cloudiness was used in these observations, the general aspect of sky in the forenoon and afternoon being entered daily.

The rain-gauge records show that more rain falls in the maritime region of the State, and in the valleys of the Hudson, Mohawk, and Susquehanna than in other sections. At twenty-nine stations the mean was greater than that of the whole State (34.9), and at thirty stations it was less. The greatest depth reported was at New York

(46.26), and the least at Lewiston (2 .23). At Buffalo, Gouverneur, Monroe, Ogdensburg, and Potsdam, the mean was below 28 inches, and at Albany, Bridgewater, Cambridge, Cherry Valley, Delaware, Jamaica, New York, North Salem, Oyster Bay, Schenectady, and Utica, it was over 40 inches. The most rain fell in summer and autumn ; the least in February and the greatest in June. From May to November the mean was above that of the year. The amount of rain falling in different years varies considerably, and, reduced to monthly means, was as follows : —

| Years. | Mean. | Above or below General Mean. | Years. | Mean. | Above or below General Mean. | Years. | Mean. | Above or below General Mean. |
|---|---|---|---|---|---|---|---|---|
| 1826 | 2.72 | —0.19 | 1835 | 2.79 | —0.12 | 1843 | 3.03 | +0.12 |
| 1827 | 3.49 | +0.58 | 1836 | 2.78 | —0.13 | 1844 | 2.69 | —0.22 |
| 1828 | 3.19 | +0.28 | 1837 | 2.99 | +0.08 | 1845 | 2.69 | —0.22 |
| 1829 | 2.76 | —0.15 | 1838 | 2.65 | —0.26 | 1846 | 2.83 | —0.08 |
| 1830 | 3.20 | +0.29 | 1839 | 2.64 | —0.27 | 1847 | 3.18 | +0 27 |
| 1831 | 3.15 | +0.24 | 1840 | 2.96 | +0.05 | 1848 | 3.28 | +0.37 |
| 1832 | 3.07 | +0.16 | 1841 | 2.66 | —0.25 | 1849 | 2.74 | —0.17 |
| 1833 | 3.03 | +0.12 | 1842 | 3.16 | +0.25 | 1850 | 3.63 | +0.72 |
| 1834 | 2.54 | —0.37 | | | | | | |

The number of solar haloes observed was 455 ; of lunar haloes, 439 ; distributed through the several seasons as follows : —

| | Solar. | Lunar. | | Solar. | Lunar. |
|---|---|---|---|---|---|
| Spring, | 196 | 128 | Autumn, | 62 | 93 |
| Summer, | 87 | 51 | Winter, | 110 | 167 |

Generally complex haloes were reported, and figures of the more important of these are given.

Auroras were observed on 1,152 days throughout the entire period, as follows : —

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1826 | 2 | 1831 | 55 | 1835 | 30 | 1839 | 57 | 1843 | 56 | 1847 | 46 |
| 1827 | 14 | 1832 | 24 | 1836 | 61 | 1840 | 73 | 1844 | 30 | 1848 | 73 |
| 1828 | 21 | 1833 | 37 | 1837 | 50 | 1841 | 73 | 1845 | 24 | 1849 | 73 |
| 1829 | 24 | 1834 | 35 | 1838 | 42 | 1842 | 35 | 1846 | 47 | 1850 | 90 |
| 1830 | 80 | | | | | | | | | | |

The greatest number of auroras was noticed in September, their distribution through the several months being as follows : —

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| January | 76 | April | 125 | July | 100 | October | 110 |
| February | 86 | May | 83 | August | 122 | November | 74 |
| March | 106 | June | 79 | September | 131 | December | 60 |

A list of stations at which auroras were observed beyond the limits of the State, was introduced to show the geographical extent of some of the more remarkable ones. Auroras were noticed on the same days in this State and in Europe on 160 occasions. In none of those seen in this State were comparative observations made with the view of determining the altitude of the aurora.

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5. ON THE PECULIAR APPEARANCE OF THE ATMOSPHERE ON THE 23D OF MAY, 1856, AT ST. MARTIN'S, ISLE JESUS, CANADA EAST. Latitude 45° 32′ north, Longitude 73° 36′ west from Greenwich, 118 feet above the level of the Sea. By CHARLES SMALLWOOD, M. D., of Toronto.

AT noon, on Friday, the 23d of May, the southwestern horizon was covered with a rather dense haze, but of a very low altitude. The zenith and eastern horizon were cloudless, and it was not till the two o'clock observation (one of the usual hours for observation at this Observatory) that any particular attention was directed to it. The two o'clock observation is thus recorded.

*Barometer*, 29.604 inches. *Thermometer*, 78°.9. Dew-point, 62°.0. Elastic force of aqueous vapor, .559. Humidity, .55. Wind southwest. Mean velocity 8.21 miles per hour. Sky cloudless, a peculiar haze in southwest and west-southwest, commencing at the horizon and rising to an altitude of 12°. *Electrometers* indicate very feeble intensity.

3 P. M., *Thermometer* indicated a temperature of 83°.4. *Barometer* falling. Wind southwest by west, 16 miles per hour. At this time the haze which had been observed at noon had increased in density, and had now attained a greater altitude, and in some measure obscured the sun's rays, giving to the sun itself a ruddy color. At 4 P. M. the obscuration was more dense, the heat was very oppressive, and at 6 P. M. the obscuration had so much increased as to completely hide the sun from view. There was no distinct form of clouds present, but there appeared a uniform dense haze.

At 6.15 the following were the observations recorded. The horizon in north-northeast, and extending to east-southeast, perfectly cloudless;

from an altitude of nearly 3° there was a peculiar yellow appearance in that part of the heavens to the visible horizon. From this altitude of about 3° hung, as it were a curtain, this dense mass of hazy matter, of a dull reddish or coppery hue, stretching out at rather a low elevation, completely obscuring the zenith, the southwestern and northwestern horizon. The sun was still completely obscured and invisible; the *barometer* now stood at 29.578 inches; the *thermometer* indicated a temperature of 73°.1. The wind, which at 3 P. M. was blowing 16 miles an hour from the southwest by west, had gradually decreased in velocity, and was now lulled into a gentle calm..

At 6.20 P. M., which is recorded here as being about the time of the greatest obscurity, the fowls had retired to roost, the frogs had begun their croak, the cows had of their own accord left their pasture; the green fields exhibited a peculiar dark-green or bluish hue, which contrasted very strongly with the eastern horizon, which was still clear, presenting a bright light of a yellow tinge. From about 6 P. M. until dark, I was occupied, with my son, in catching leaves and ashes which were carried by the wind. The leaves were of exogenous plants of the class Cupuliferæ and Acerineæ (mostly beech and maple). They appeared scorched and blistered, as if caused by great heat. The ashes continued falling most part of the night, at least till about 2.20 A. M. of the 24th, when the wind veered by the north to due east. On submitting these ashes to examination, I found they consisted of silicious (flinty) matter, leaving a permanent mark on glass. They were also mixed up with light vegetable matter. From the size of the leaves, I presumed they were not of this year's foliation, and this was verified upon further examination; and this may account in some measure for the distance they were carried, and no doubt aided by the dense medium by which they were surrounded, or in which they floated. They were all caught before reaching the ground, so that no error could possibly occur.

I shall now give a report of the appearances as they occurred at Bytown. The newspaper says: —

"On Friday afternoon last, the wind brought up, apparently from the rear of the Gatineau Mountains, opposite this city, a vast cloud, which gradually rose to the zenith, and finally spread over the whole face of the heavens. A more extraordinary appearance we never saw. The cloud itself, particularly towards the zenith, was of a lurid

copper color, while towards the quarter from which the wind came there was a large spot of lighter color, absolutely fiery, very like what sailors call the 'ox-eye,' which is seen amidst the masses of dark clouds which prelude a hurricane on the west coasts of Africa. It is no exaggeration to say, that the scene was a most awful one, and every one expected a tremendous outbreak of the powers of nature; some predicted an awful thunder-storm; others a hurricane of wind and deluge of rain; but nothing came of it; the clouds gradually passed away, and the evening was fine. During the continuance of this dense cloud, a few ashes and some burnt leaves fell in the streets in various places, and our own opinion is, that all this most remarkable appearance was the result of an enormous fire in the forest, far up on the southern slope of the range of mountains which terminate on the Saguenay, passing behind Three Rivers and Quebec. If it be so, the conflagration must have been of an astounding character to have produced such results here, and it is evident that the scene of the fire must have been far off, and probably in a tract of land where none but the red man puts his foot, for we have heard of no fire anywhere near civilized settlements in that direction.

"On the next morning, Saturday, we experienced a heavy thunder-storm, with rain, and in the afternoon there was a little thunder, with showers. The heavy rain of Saturday must have swelled the tributary streams, and so will aid the timber-driving."

"Since the publication of our paper, this morning, we have received a communication from Pembroke, the substance of which we communicate to our readers in the form of an extra. The extraordinary phenomenon of Friday, alluded to in our columns of to-day, is now fully accounted for; but we must confess ourselves at a loss to understand how a vast cloud of smoke arising from a fire above Pembroke, could make its first appearance here from behind the mountains which skirt the township of Hull. We can only account for it by applying Reid's theory of storm, that the wind blows in circles, and that the storm of wind which brought the great cloud past this city must have circled to the westward from Pembroke. We may be talking nonsense, for we pretend to no accurate acquaintance with meteorology, but in our simplicity can account for the phenomenon in no other way. Our correspondent says that a great fire broke out in the woods near Pembroke on Friday, that many farmers were burnt out, and that nothing was expected but the destruction of the whole town. The wind fortu-

nately changed, but all the inhabitants had everything ready to take to the river as their only chance of safety.

"On the Petewawee River, ten miles from Pembroke, the women and children had to take to the river to save their lives; two or three saw-mills, a tavern, and all the houses in the settlement, are destroyed. In Pembroke, at two o'clock on Friday, nothing could be seen but sheets of flame, which appeared to surround the place; the sun was as red as blood, and the whole sky seemed in a blaze; the scene was so frightful that many people believed, in their terror, that the Last Day was at hand. No one thought of saving any of their possessions; the only thought was to escape by getting into the river. About eight o'clock at night the wind, which had been blowing straight for Pembroke, calmed down, and the town was saved. At four in the afternoon the smoke was so dense that the people were almost on the point of suffocation, and it was so dark that no one could see across the street. All describe the scene as a most frightful one. We have heard of thirty families burnt out, and who narrowly escaped with their lives. Our correspondent says, that the sound of the roaring flames actually shook the ground, and the noise of the falling trees was like the rattling of a line of heavy wagons over a corduroy road; the country about is half ruined, and a number of bridges have been burned. We are promised further particulars."

Such were the appearances within 60 miles of the conflagration, and the distance from Pembroke to St. Martin's is not less than 200 miles. Burnt leaves and ashes were picked up in Montreal, and the amount of ashes in this neighborhood was very considerable.

The peculiar appearance of the atmosphere at this place was caused no doubt by the interception of the solar rays by dense haze, consisting of smoke and vapor. The white light was absorbed, giving rise to the predominant yellow ray. The green fields were of a bluish tint. It would seem that it was only the light ray that was intercepted. The *calorific ray* does not seem to have at all absorbed, for there was no fall of the thermometer; in fact, the heat was oppressive. The *chemical* or *actinic* ray seems also to have retained its action, for chromatype paper exposed was easily acted upon, as was also paper wetted with the solution of nitrate of silver. I had no opportunity of examination with the polariscope; the prismatic spectrum was deficient in the yellow ray. I may remark, that a very violent storm of thunder and lightning occurred on the following morning.

# PART II.

## NATURAL HISTORY.

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### I. GEOLOGY AND GEOGRAPHY.

1. PLAN OF DEVELOPMENT IN THE GEOLOGICAL HISTORY OF NORTH AMERICA. — With a Map. By PROFESSOR JAMES D. DANA, of New Haven.

ON other occasions, I have discussed at some length, the outline and surface features of the continents, the parallel courses of island groups, and the relations between the structure of the continental borders and the extent of the adjoining oceans; and I have endeavored in connection to elucidate the great principle of geological dynamics, which is at the basis of these characteristics of our globe.* I propose at this time to point out the relations between the operations of this principle or agency and the special geological history of the North American continent.

To render this application of the subject intelligible, it is necessary to review briefly the fundamental facts just alluded to. For this purpose, I would direct attention to a Mercator's Chart of the World (see plate), on which the whole is open to examination, — such a chart being a miniature representation of the facts themselves, and the order observed among its parts, the syllables which spell out the principles.

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* Am. Jour. Sci., [2], ii. 335, 352, iii. 94, 176, 381, iv. 88; Report, Geol. Expl. Exped., 756 pp. 4to., 1849, pp. 11, 414, 429; Proceedings Amer. Assoc. vol. ix. Providence Meeting, 1855.

In the first place, note the two great oceans, the Atlantic and the Pacific, — both widening south, and coalescing in a vast ring of ocean around the south pole, while narrowing north and uniting in a small arctic sea. The Indian Ocean is a third north and south ocean; but it reaches north only a little ways beyond the equator.

As the Atlantic is less than half the breadth of the Pacific, so the American continent is less than half the breadth of the great Orient, including Europe, Asia, and Africa. It is seen also that while the North Atlantic trends off to the north-east, and the whole Atlantic is a zigzag channel with a main *north-east* course, the Pacific is a *north-west* channel, its longest diameter (represented by the line M M), being at right angles nearly with the trend of the Atlantic (N N). This longest diameter, moreover, corresponds with the general trend of the Pacific islands; for these islands have a nearly parallel course all through the ocean, the New Hebrides, Kingsmills, Samoan, Tahitian, Marquesas, and Sandwich islands, lying in approximately parallel lines.* In the

* I may here add, what I have elsewhere explained at length, that the trends of the Pacific, while having a general correspondence of direction, pertain to two systems, one the Central Pacific, the other the Australasian. The Central Pacific begins in the Paumotu Archipelago, or rather still further east, in Easter Island and Gomez; is thence continued on a west-north-west course, by the Society Islands, and the Hervey Islands more south; thence by the Samoan and Fakaafo groups; thence more north-westerly by the Vaitupu and Kingsmills, to the Radack and Ralick groups, which run nearly north-north-west; making thus a great sweeping curve, of several strands, over 6,000 miles long. The Sandwich or Hawaian islands on the north side of the equator (2,000 miles in whole length) is the opposite or northern side of the same system, slightly curving with the convexity to the north: while the Marquesas and the Fanning or Washington group lie along the axis of this great Central Pacific area. The other system is concentric around Australia, (New Holland). The line of New Hebrides, near north-west in course, is continued in the Salomon Islands, and New Ireland, becoming gradually east and west in the Admiralty Islands, north of New Guinea. The line of New Caledonia, another curving strand in the system, is continued in the Louisiade group and New Guinea, and becomes east and west in western New Guinea. The foot of the New Zealand boot, and the Coral Archipelago between New Caledonia and Australia, accord with the system. The position of these lines concentric around Australia corresponds with the idea that the position and extent of this continent has had some influence in determining the directions.

These two systems, the Central Pacific and Australasian, though so distinct, are yet bound together in one. For while the great central range has its main course

body of New Zealand, however, and some other parts, the transverse trend of Eastern America is represented.

Now what is the relation between the borders of the continents as to features and structure, and the extent of the oceans?

1. Look first to North America. Observe the general direction of the coast conforming to the prevalent trends of the globe, the north-east and north-west, and thus giving it its triangular form. See the low Appalachians facing the *small* Atlantic, the lofty Rocky Mountains, mostly a double line of heights, facing the *broad* Pacific, besides a second towering range, the Cascade and Sierra Nevada, nearer the sea. May we not say, *As the height of the Appalachians to the size of the Atlantic, so is the height or extent of the Rocky range to the size of the Pacific?*

In South America, there is the same relation,—the low Brazilian mountains on the Atlantic side, the lofty Andes on the Pacific, and the latter exceeding the Rocky Mountains as much as the South Pacific exceeds the North Pacific; so that we may make another proportion, *As the height of the Rocky Mountains to the North Pacific, so is the height and boldness of the Andes to the South Pacific.*

In the Orient, the mountains towards the Atlantic, or those of Europe, are low and limited, compared with the long and lofty ranges of the Pacific side; and these last are inferior to the Himalayas, the sublimest heights of the world, which face the Indian Ocean,—a large and open ocean, while the Pacific towards Asia is much encumbered by islands.

In Africa, the loftiest and longest mountains are those of Abyssinia, on the east, facing the Indian Ocean, some of whose ridges are eleven to fourteen thousand feet in height, and one peak near the equator is 20,000 feet. In Australia, the Australian Alps, as they are called, are on the east fronting the Pacific, here the wider of the bordering oceans.

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along the Kingsmills and Radack groups, it sends off at the Kingsmills, a western branch, the Carolines, which is actually parallel with the lines of the Australasian system.

The transverse trend of New Zealand, which is continued in the Friendly Islands north, is the correlate of the north-western, the two having a mutual dependence, and together distinguishable in many groups of islands as well as in the features o the continents.

Thus all over the world, the highest mountains stand fronting the largest and deepest oceans; and the "rule of three" statement of the fact scarcely conveys a wrong impression.

2. We observe further that the coasts are in general so turned as to face the widest range of ocean. The Appalachians with the neighboring coast do not face north-east towards the European continent, but south-east, towards the great opening of the Atlantic between America and Africa. So on the west side of North America the Pacific coast faces, not towards Asia, but south-west, where the broadest range of ocean is before it.

3. Consider now a little more closely the structure of these ocean borders. How is it as to the effects of heat or volcanic action?

In North America, on the side of the *small* ocean, the Atlantic, we find metamorphic rocks, some trap dykes, and a few tepid springs. On the side of the *great* ocean, the Pacific, all these phenomena occur, and besides, some of the grandest volcanoes of the globe, while basaltic floods have buried out of sight almost all other rocks over a considerable part of the country. Mount St. Helens, Mount Hood, Mount Shasta, and many others, twelve to eighteen thousand feet high, make a majestic file of fire mountains not yet wholly extinct. May we not then say, *As the size of the Atlantic to the action of heat on the Atlantic border, so is the size of the Pacific to the action of heat on the Pacific border?*

In South America, there is a direct repetition of the same facts on a still grander scale: the Brazilian side, with metamorphic rocks and no volcanoes; the Pacific side, with volcanic heights of 20,000 feet and upward.

In the Orient, there are some small volcanic operations on the Atlantic side; but an unnumbered host down through Kamtschatka, Japan, and the islands south on the Pacific side.

In Africa, there are great volcanoes in the Red Sea and the lofty Abyssinian mountains, and only a few on the east, in the Gulf of Guinea, where, in fact, the continent opens on the Southern Ocean and not simply on the narrow Atlantic; the volcanoes are at the junction of the two lines, in or near the Bight of Biafra.

4. Again, these effects of heat are confined mostly to the region between the crest of the border mountains and the ocean, and are most intense towards the coast line. Thus the crystallization or metamor-

phism of Eastern North America, from Labrador to Georgia, is strongly marked towards the ocean, and diminishes going westward. So on the Pacific side: the great volcanoes are not on the east or landward side of the crest, for there is not a volcano on that side, but on the seaward side, and not very far from the ocean. Thus we may almost say, *The nearer the water, the hotter the fire.*

5. Again, the mountains that make the borders, consist as is now well known since the surveys of the Professors Rogers, of rocks that have been pressed up out of place into a series of immense folds, like the folds we may make in paper by pressing laterally; only the rocky folds are many miles in range and of mountain height; and these folds or plications and displacements are most numerous towards the ocean, and are parallel nearly to the ocean. Hence again, *The nearer the water, the vaster the plications of the rocks.*

6. Over the interior of North America, there are not only no volcanoes, but there never have been any since the earlier Silurian, as shown by the absence of their remains among the strata; and this is so, notwithstanding the abundance of salt water over the regions in those ancient times. Over the interior of Asia there are no volcanoes, as is well known, except the three or four in the Thian-Chan Mountains. The great volcanic belt of the Orient stands out a short distance from the water-line of Asia, in the Japan range of islands, thus directly edging the oceanic basin; for the intervening region of shallow waters is properly a submerged part of the continent.

7. In contrast with this non-volcanic character of the interior of the continents, the islands of the oceans, it should be remembered, are all volcanic where not coral, and those of coral probably rest on a volcanic basis. Dhawalagiri, in the Himalayas, 28,000 feet high, is granitic; and surely we might have looked for some granitic peaks among the central islands of the oceans: but there are none.

At the same time, as others have remarked, the transverse seas which divide the Northern and Southern continents, the East Indies, the Mediterranean, and West Indies, are characterized by volcanoes.

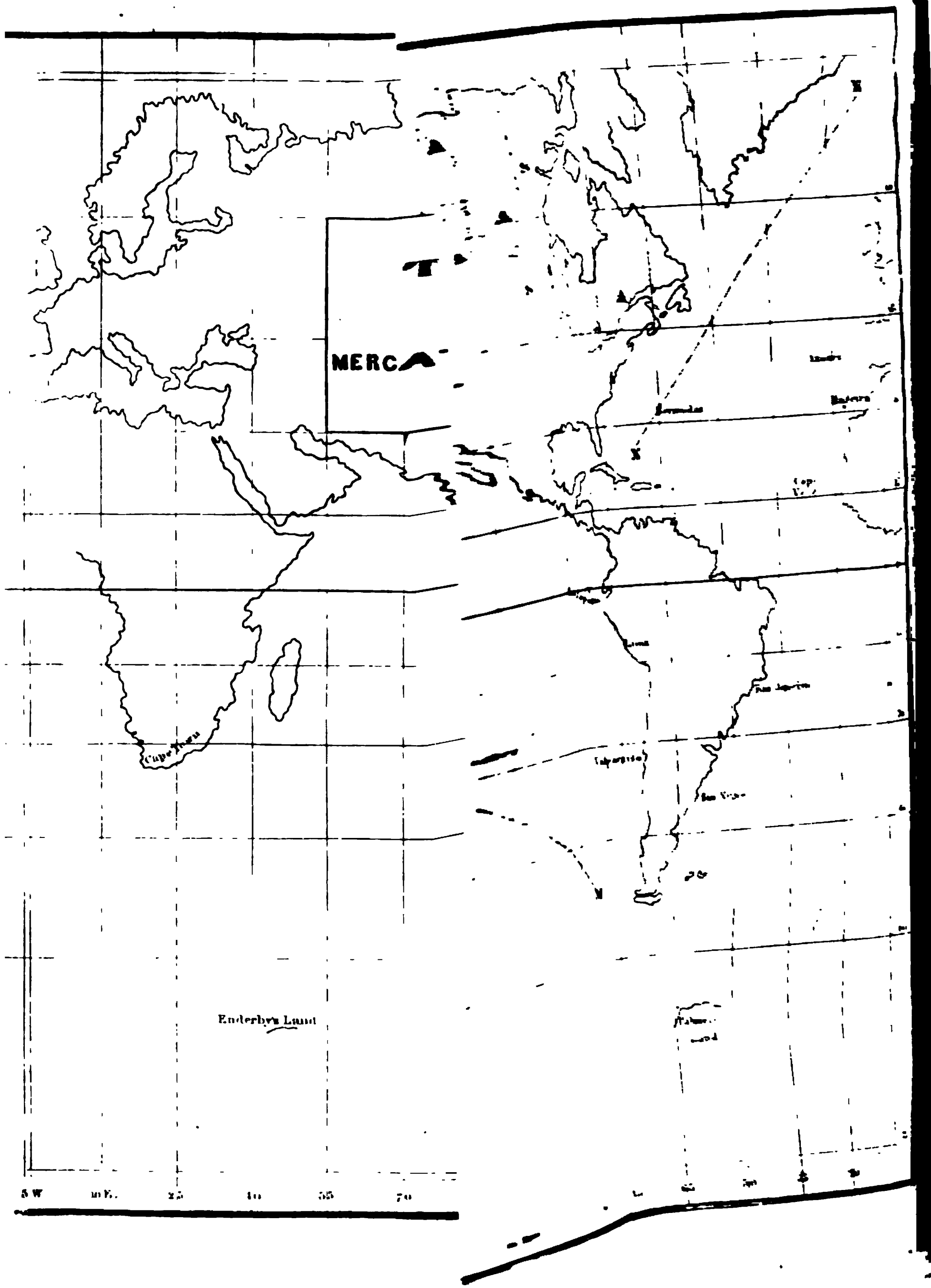
If, then, the typical form of a continent is a trough or basin, the oceanic borders being raised into mountains; if these borders are so turned as to face the widest range of ocean; if the height of these border mountains and the extent of igneous action along them is directly proportioned to the size of the oceans, — the Pacific, accordingly, being

There must be system in the intimate structure of the crust. For if it was once fluid, and is now one or two scores of miles thick, all this thickness beyond that of the first film has been produced through gradual, exceedingly gradual and prolonged cooling, adding, by downward increase, to the solid surface arch : and if ice over a pond when thickening in this same way by additions downward to the surface film takes a crystalline texture perpendicular to this film, as has been proved, we may safely infer that the crystallization of the earth's crust as it slowly thickened would have taken a regular structure, and the more surely since we know that the mineral feldspar, which gives a cleavage structure to granite, is the prevailing mineral in all igneous rocks. Thus we approach some explanation of the prevalence of two great systems of trends in the features of the globe. But this subject we pass by, to the one which more immediately concerns us, — the surface features of the continents.

The contraction to which I have alluded, going on after a crust was formed over the earth, would necessarily fracture, displace, or wrinkle the crust, as the same cause, contraction, wrinkles a drying apple. The large rind is more than sufficient for the contracted sphere; and the drawing downward of some parts must cause the bulging of others. If any large areas of the crust were sinking more than the rest, this very subsidence would necessarily push up the borders of these areas into angular elevations or folds; and it follows necessarily, — the larger these areas the higher the border elevations.

These are the simple principles. The oceanic basins are these areas of greatest subsidence; and hence would necessarily flow the law, already established as a matter of fact — the larger the ocean, the higher the mountains on its borders, the deeper the fractures and displacements there, and the vaster the outflow of internal heat and lavas. The size, therefore, of the oceans, that is, their extent and depth, is relatively a measure of the force exerted on their sides.

The wrinkles or elevations on the globe seem large when man measures them by comparison with his own stature. But a section of the land, true to nature, corrects this misapprehension. In a section of the North American continent, drawn to a scale twelve feet long, one ninth of an inch will stand for an altitude of 10,000 feet; one sixteenth of an inch for the White Mountains, and about three tenths for the Himalayas.


MERC
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this review of principles, let us now turn our attention to
merica and seek out its plan of development.

e triangular form of the continent has been noted and its sim-
ı boundary: and it should be observed that the continent is
to the west of South America, so as to possess this simplicity
ary and therefore of moulding forces in its highest perfection.*
ll Atlantic on one side, and the great Pacific on the other, in-
proximately the relative amounts of force from the two direc-
south-east and south-west, during the progressive ages of the
— that to the eastward the power was comparatively moderate,
lding up the Appalachians, and to the westward it was strong
ıty, even to the raising of the Rocky range and opening the
canoes of Oregon. We thus learn, with a degree of precision
ave been anticipated, the direction and efficiency of the great
ıg forces.

now at American geological history from this point of view,
ider where was the first germinant spot of the growing conti-
what was thence onward the course of development under
nce of this agency.

ırliest spot or primal area will be that of the Azoic rocks, the
ıe geological series. Such an area (see Chart, A A A) extends
thern New York and Canada, north-west to the Arctic Ocean,
ween the line of small lakes (Slave, Winnipeg, etc.) and
Bay. East and west, it dips under Silurian strata (S S); but
free from superincumbent beds, and therefore, even in the
age, it must have been above the ocean. And ever since, al-
ıbject, like the rest of the world, to great oscillations, it has
y held its place with wonderful stability, for it is now, as
then, not far above the ocean's level.

rea is central to the continent; and, what is of prominent in-
lies parallel to the Rocky Mountains and the Pacific border,
ing that the greater force came from that direction in Azoic
well as when the Rocky Mountains were raised. Thus this
, the germ or nucleus of the future continent, bears in itself

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ɔntrast with Europe in this respect is striking, and accounts, as I have
ess, &c., Proc. Amer. Assoc. vol. ix. p. 10, 30,) for the greater simplicity
merican Geology.

evidence with respect to the direction and strength of the forces at work. The force coming from the Atlantic direction has left comparatively small traces of its action at that time. Yet it has made its mark in the Azoic stretching through Canada to Labrador, in the dip and strike of the New York Azoic rocks, in the direction of the channel of the St. Lawrence and the north-west coast of Lake Superior, as well as the bearings of the Azoic of Missouri and Arkansas, and probably also in the triangular form of Hudson's Bay. Against this primal area, as a stand-point, the uplifting agency operated, acting from the two directions, the Atlantic and the Pacific; and the evolution of the continent took place through the consequent vibrations of the crust, and the additions to this area thereby resulting; the ocean in the mean time pursuing its appointed functions in the plan of development, by wearing exposed rocks and strewing the shores and submerged surface with sand, gravel, or clay, or else growing shells, corals, and crinoids, and thus storing up the material of strata and burying the life of successive epochs.

These long secular vibrations, movements by the age rather than day, dipping the surface and raising it again in many and varying successions, were absolutely essential to the progress. Had the continent been stable, there could have been no history, no recorded events of changing life and alternating deposits: all would have been only a blank past. These forces, therefore, working mainly from the south-east and south-west, were actually organizing forces, essential to the completion of the continent, — to the production of its alternations of limestones, shales, sandstones, and conglomerates, and its sweeping catastrophes burying the old, preparatory for higher, forms of life; — the continent in the course of these movements, being at one time, it may be, just beneath the ocean's surface, and having beds of sand and gravel accumulating under the action of the waves; then in somewhat deeper and clearer waters, with limestones forming from coral or crinoidal plantations or the growth of shells; then, perhaps, rising from the waves, bringing death upon its sea tribes in one universal desolation; then, sinking slowly in the waters again, and varying in its accumulations from sandstones to shales, pebble beds or limestones, with the depth and the currents; and then again above the tides, although destruction to all the life of the ocean was in the movement; and, perchance, lying in the open air for an era, to receive the mists and rains

and sunshine, and become luxuriant through new creations with broader prairies than now cover the West. Alternations like these were again and again repeated, as geology has shown.

Through these means, the continent, which was begun at the far North, a region then tropical but afterwards to become inhospitable, gradually expanded southward, area after area as time moved on being added to the dry land.

First, as the facts show, the Silurian deposits of Canada and the North, adjoining the Azoic, were left above the sea, for these rocks there are not overlaid by later beds; and, therefore, were not the sea-bottom of later seas. Next, the adjacent Devonian were added to the main land as far south as Southern New York and around by the west; for, as the New York geologists have shown, the carboniferous beds which come next do not reach into that State. By the time of the Jurassic period, the continent had expanded much farther to the southward, for the carboniferous rocks over the land were out of water, their beds having already been folded up and elevated in the Appalachians. The red sandstone of the Connecticut Valley and of the Atlantic States from New York to Alabama leave little doubt as to the water-line of that era. In the Cretaceous period the continent had farther expanded along the Atlantic; but in the Mississippi Valley the Mexican Gulf still extended north even to the head waters of the Missouri. Next, as the Tertiary opened, the continent had yet more widely enlarged its bounds, south and south-east; and if the waters of the Mexican Gulf for a while claimed a place over some part of the Nebraska plains, as late observations suggest, by the close of the period the continent in this direction had nearly reached its full maturity. These steps of progress are indelibly marked in the position, and obvious sea-coast, off-shore, or estuary origin of the Jurassic, Cretaceous, and Tertiary beds of the country.

Passing towards the Pacific, we find evidence in the carboniferous limestone that the Rocky Mountains were mostly under shallow water as the Carboniferous age opened, the mountains themselves unborn. Later in the Cretaceous and Tertiary periods, as the rocks towards the coast testify, the continent had extended far to the south-west, and was nearly complete in that direction, as well as to the south and south-east.

Thus the enlargement went on to the southward, each period making

some addition to the mainland, as each year gives a layer of wood to the tree. Not that this addition was free from oscillations, causing submergences, for these continued long to occur; but the gain, on the whole, was a gain — a progress; and the moving ages made the accession a sure and permanent gain as the continent became more stable.

II. But in the statement that the growth of the continent was to the south, south-east, and south-west, we assert only the most general truth respecting it. The continent has its special features as much as any being of organic growth, and the elimination of these features is to be traced to the same system of forces. The Appalachian range on the east, the Rocky Mountains and the subordinate chains on the west, the lower lands and lakes of the interior, all in a systematic relation, are the more marked of these features; and the vast river systems, with the broad alluvial flats and terraced plains, the wide spread drift, the denuded heights and channelled slopes and lowlands, are subordinate peculiarities of the face of the continent.

The Appalachian range of heights, as I explained a year since, was commenced in the Silurian age, and even earlier long before a trace of the mountains had appeared.* The force from the south-east, in the dawn of the Palæozoic era, had made the Appalachian region generally shallower than the Mississippi Valley beyond. The vast sandstone and shale deposits of the region bear marks in many parts of sea-shore action, while the limestones which were forming contemporaneously farther west, indicate clearer and somewhat deeper seas; and the patch of Azoic in Northern New York, lying at the northern extremity of part of the range, points to an anterior stage in the same course of history; so that, in early time, long before there were mountains, the future of the continent, its low centre and high borders, was foreshadowed. We can hardly doubt that the region of the Rocky Mountains was in the same condition, in the main, with that of the Appalachians. Moreover, these borders, or at least the eastern, for ages anterior to the making of the mountains, were subject to vastly greater oscillations than the interior; for the Silurian and Devonian sandstones that occur along from New York to Alabama are of great thickness, being five times as thick as the limestones and associated deposits of

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* Address, &c., see note page (9).

the same age to the west. A limestone bed, moreover, is of itself evidence of comparatively little oscillation of level during its progress.

We hence learn that in the evolution of the continental germ, after the appearance of the Azoic nucleus, there were two prominent lines of development; one along the Appalachian region, the other along the Rocky Mountain region—one, therefore, parallel with either ocean. Landward, beyond each of these developing areas, there was a great trough or channel of deeper ocean waters, separating either from the Azoic area.

The Azoic, as has been indicated, has something of a V shape, (or V,) with Hudson Bay between its arms. This succeeding step of progress is the partial development of a larger V outside of and parallel to the Azoic nucleus. The channels alluded to lie between the two V's. The bar of the outer V on the left is of great breadth and made up of several broad parallel bands or ranges of elevations; that on the right is quite narrow comparatively, yet also etched in several parallel lines.

The Mexican Gulf is all that remains of the larger of these channels. Its waters once stretched to the Arctic Sea, and were in early time but the deeper part of the continental ocean. Later, as the ages moved on, there was land to the north, and a line of fresh-water lakes along its former course; and the gulf reached no higher than the head waters of the Missouri. Later still, and its limits became more contracted, till now the full-grown continent has but her foot in the salt water.

The Gulf of St. Lawrence marks the outlet of the other channel, and the River St. Lawrence its course. The great lakes, as well as the smaller lakes north, lie near the limits of the Azoic nucleus within these ancient troughs or depressions; and the largest lake, Lake Superior, is at the junction of the two lines.

Such was the law of growth. The molecular forces *beneath* the continent, from the progressive cooling there going on, were not idle, and must have modified the results. But the main action causing the lifting and sinking of the crust and the final gain to the land, proceeded from the directions of the oceans. The inequality in the forces from the two directions, as well as in the form and depth of each oceanic or subsiding area whence the forces mainly came, would necessarily have

produced many irregularities in the results, as I have remarked in another place,* and will not now dwell upon.

The Pacific region has always been true to its own grandeur. The force from that direction not only made the Rocky Mountains to rise and a file of lofty volcanoes to light up its waters, (while the most the gentler Atlantic could accomplish was a bending up of the strata into Appalachians, and a baking of some of the beds,) but it also added tenfold the most dry land to the continent; and even after the Tertiary rocks were deposited, it elevated the continental border at least two or three thousand feet, — ten times beyond what happened on the Atlantic side.†

But look further, and consider that the great lines of elevation on the Pacific side are parallel nearly to the islands of the ocean; that these islands are like a long train stretching off from Asia to the east-south-east; that New Hebrides, New Caledonia in the south-west, with the foot of the New Zealand boot and North-western Australia, conform to the general parallelism; and it will then be comprehended that we have been considering not simply a continental system of progress, but one involving the whole globe. It appears also from the history of the coral islands of the Pacific, that while the Tertiary and Post-tertiary elevations were going forward on the Pacific border of North America, a slow and gradual subsidence was in progress over a parallel region across the middle of the ocean. The axis line of the Pacific is not only the main trend of its lands, but is also nearly the course of the great subsidence which is indicated by the history of the coral islands.‡

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* Amer. Jour. Sci. [2], vol. iii.

† Whatever doubts may exist as to the cause, there can be none as to the actuality of the force on the two sides, the Atlantic and the Pacific. The elevation of the mountains on each border is proof beyond question; and their relative extent and height is evidence indubitable as to the relative amounts of force exerted. The parallel *folds* on the Atlantic side show that there it *was actually lateral* force from the south-east; and the several parallel ranges on the Pacific side, parallel to the ocean, are proofs of similar lateral action there, but from the south-west. Then the dominance of these two trends in the uplifts over the whole continent in its oldest and newest regions and rocks, are like the warp and woof of a fabric, determined by the organizing forces themselves of the structure.

‡ Amer. Jour. Sci. vol. xlv., (1843,) 131, and [2], iii. 396, (1847). One conse-

III. I have said that these two systems of forces — the south-east and south-west — continued to act through the Tertiary period, working out the continent, and bringing it nearly to its adult extent. At the meeting of this Association at Providence I pointed out the fact that at the close of the Tertiary there was a change in the movement; that during the following period, the Post-tertiary, there were high-latitude oscillations; and I endeavored to show, that there was first an elevation of the continent over the north for the first, or glacial epoch; then a subsidence (as shown by the sea-shore deposits on Lake Champlain, and the highest terrace of the lakes and rivers) during a second or Laurentian epoch; and finally, an elevation to its present height, for the third or Terrace epoch. Whether the elevation for the Drift epoch be admitted or not, all agree that the oscillation attending it was a northern phenomenon. These several changes thus affected mainly the latitudes north of the middle of the temperate zone, or were but slightly felt to the south of this. It is a remarkable fact that the coasts of the Arctic regions, which have now been rather widely explored, have not presented any Jurassic, Cretaceous, or Tertiary deposits, and there is, therefore, no evidence of their having been in those eras under water. Such beds may hereafter be detected; but the great fact will still remain, that they are there of limited extent, if not wholly absent. As far as known, there is no Tertiary on the coasts north of Cape Cod. All development or growth there seems to have ceased, or nearly so, with the Palæozoic era or the close of the Carboniferous age. But there are Post-tertiary deposits in the Arctic regions in many places, situated hundreds of feet above the sea, containing shells of existing Arctic species. This alone, independent of other evidence, would prove a change in the conditions of geological progress after the Tertiary period. The necessary inference is, then, that as long as the south-west and south-east forces were in active play,

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quence of these facts and principles may be here alluded to. If the position of the Atlantic and Pacific has determined the main directions of the organizing forces through all time, and if, owing to the direction, as the facts show, elevations having the *same* strike or trend have been formed in successive geological ages, it is evident that the elevation theory of mountains, sustained by Elie de Beaumont, must be received with much hesitation. One dial-plate for the world, such as he has deduced mainly from European geology, is a splendid hypothesis; but it may not mark time for America or the other continents.

and the extremities of the continent were thereby in process of growth, there was little change going on in the far north. But when the continent was nearly finished, its extremities grown, and the stability consequent upon adult age acquired, then, through a series of oscillations, a course of development was carried on in the more northern regions, giving a final completion to the continent — an action, which, as I have elsewhere explained, involved the higher latitudes about the whole sphere, north and south of the equator.*

We shall understand more definitely the relations of the later to the older oscillations, if we consider that all were due to one grand cause, influencing the whole extent of the continent even to the Arctic Ocean; that the force from the north, the south-east, and the south-west, according to the principle explained, was proportioned approximately to the sizes of the oceans, the Arctic, the Atlantic, and the Pacific; that the greater forces from the south-east and south-west acted against that from the north and through their superior strength or the concurrent greater flexibility of the crust, kept up those vibrations in the progress of which the border mountains were made; but at last, the south-east and south-west action almost ceasing through the stiffening and uplifting of the crust, then the northern force, having a stable fulcrum, made itself felt in the long and slow oscillations of the Post-tertiary. Under this mode of view it will be seen that all was part of one system of development.

If we rightly apprehend the results of the Post-tertiary period, we shall perceive that there was vast importance in these finishing operations over the sphere: — that during its progressing centuries, the great phenomena of the drift took place, covering hills and plains with earth; that the valleys for our rivers were then either made or vastly enlarged; that immense alluvial plains were spread out in terraces over the interior and in flats along the shores; that thus a large part of the brighter features of the globe were educed. The mountains of the earth at last stood at their full altitude, having gained some thousands of feet since the Tertiary; and rivers, true offspring of the mountains, taking their size from the size of the mountain ranges, were sent on renovating missions over the breadth of the continents. Indeed, the upper ter-

* Address, &c., loc. cit.

races of the rivers show that during the Post-tertiary, these interior waters had an extent and power vastly beyond what the streams now exhibit; — an extent which is yet unexplained, unless attributable, as I have suggested, to the declining snows of a glacier epoch. In their strength, they deeply channelled the hills, and wrought out much of the existing sublimity of mountain architecture. There was the elimination of beauty and of immediate utility in every stroke of those later waters, in marked contrast with the earlier operations of rock-making and mountain-lifting; for those very conditions, those special surface details, were developed, that were most essential to the pastoral and agricultural pursuits with which man was to commence his own development, while that grandeur was impressed on the earth that should tend to raise his soul above its surface.

This transfer of the process of development from the extremities to the more northern regions, thence evolving these new and more refined qualities of inorganic nature and humanizing the earth, has a parallel in organic growth; for the extremities are finished and adult size attained before the head and inner being are fully perfected. The analogy is fanciful; yet it is too obvious a parallelism to be left unsaid on that account.*

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* I have alluded on a former page to an analogy between the progress of the earth and that of a germ. In this, there is nothing fanciful; for there is a general law, as is now known, at the basis of all development, which is strikingly exhibited, as Professor Guyot has shown, even in the earth's physical progress. The law, as it has been recognized, is simply this: — Unity evolving multiplicity of parts through successive individualizations proceeding from the more fundamental onward; a law wrought out and developed, especially with regard to the inorganic history of the globe, by Professor Guyot. (See his Earth and Man.)

The earth in igneous fusion, had no more distinction of parts than a germ. Afterwards, the continents, while still beneath the waters, began to take shape. Then, as the seas deepened, the first dry land appeared, low, barren, and lifeless. Under slow intestine movements and the concurrent action of the enveloping waters, the dry land expanded, strata formed, and as these processes went on, mountains by degrees rose, each in its appointed place. Finally in the last stage of the development, the Alps and Pyrenees and other heights received their majestic dimensions and the continents were finished out to their very borders.

Again, as to the history of fresh waters. — The first waters were all salt, and the oceans one, the waters sweeping around the sphere in an almost unbroken tide. Fresh waters left their mark only in a rain-drop impression. Then the rising lands

Thus, then, the continent was completed. Contraction was the power, under Divine direction, which led to the oscillations of the crust, the varied successions in the strata, and the exuviations of the earth's life, era after era. Acting from the Atlantic and Pacific directions, it caused the southern prolongation of the growing land from the icy north to the tropics, while it raised mountains on the borders, and helped to spread the interior with plains, varied slopes, and lakes. And, finally, through its action over the north, the surface received its last touches, fitting it for a new age — the Age of Mind.

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## 2. On the Parallelism of the Rock Formations of Nova Scotia with those of other parts of America. By J. W. Dawson, A. M., F. G. S., &c.; Principal of the McGill College, Montreal.

The peninsula of Nova Scotia is occupied entirely by rocks of the Silurian, Devonian, and Carboniferous systems, and an overlying red sandstone series associated with beds of trap. It is especially remark-

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commenced to mark out the great seas, and the incipient continents were at times spread with fresh-water marshes into which rills were flowing from the slopes around. As the mountains enlarged, the rills changed to rivers, till at last the rivers also were of majestic extent, and the continents were throughout active with the busy streams, at work channelling mountains, spreading out plains, opening lines of communication, and distributing good everywhere.

Again, the first climates were all tropical. But when mountains and streams were attaining their growth, a diversity of climate, (essential to the full strength of the latter,) was gradually evolved, until winter had settled about the poles as well as the earth's loftier summits, leaving only a limited zone, — and that with many variations, — to perpetual summer.

The organic history of the earth, from its primal simplicity to the final diversity, is well known to exemplify in many ways the same great principle.

Thus the earth's features and functions were successively individualized: — first, the more fundamental qualities being evolved, and finally those myriad details in which its special characteristics, its magnificent perfection, and its great purpose of existence and fitness for duty, largely consist.

able for the great development and fine exposure of the carboniferous rocks, and for the circumstance, in part connected with the former, that all the formations older than the coal have been greatly fractured and metamorphosed before the carboniferous period, so that the coal rocks are quite unconformable to those of the Devonian period. I propose in this paper to give a general account of the latest state of our information as to the equivalency of geological changes and formations in this outlying portion of the American palæozoic and mesozoic formations, with those in the United States and Canada.

1. *Modern changes of level* in the western part of Nova Scotia, are evidenced by the occurrence of stumps of the pine and beech *in situ* at a depth of thirty feet below the level of the high tides in the upper part of the Bay of Fundy; and there are indications that the greater part of the marsh lands of that bay are based on such submerged upland. The observed evidence of this submergence depends on the great rise and fall of the tides of the bay, so that in other parts of the province similar subsidence may have occurred, without leaving the same traces. The best instance of a submerged forest in Nova Scotia, or perhaps in Eastern America, occurs near Fort Lawrence, and is described in the Proceedings of the Geological Society of London, for January, 1855.

This modern subsidence connects itself with that said to be in progress in the south of Newfoundland, and with the submarine forests that have been described by Professor Hitchcock, Mr. Gesner and others, as occurring in Prince Edward Island, the island of Grand Manan, and the coast of New England.

2. The Boulder formation is almost universally diffused in Nova Scotia, and, as in many other parts of the world, consists of two members, a boulder clay, indicating intense frost and continued subsidence, with ice drift of coast stones and boulders; and superficial gravels and sands, marking the action of the sea during the emergence of the country. Under the boulder clay the surface is generally polished and striated. No marine shells have been discovered, but in one place I have observed a bed of peat with roots of coniferous trees beneath the boulder clay; and in some other localities old stratified sands and gravels have been covered by it. Remains of mastodon have been found in the superficial gravel.

The distribution of boulders has been determined by currents by no

means uniform, and modified by the physical features of the country. The direction of the striæ and furrows is most frequently north-east and south-west, coinciding with that of the hills and valleys of the country, and with that of the present northern current of the coast, as well as with the prevailing course in other parts of the continent; but locally striæ are found to run east and west, and north and south, and there are often two sets crossing each other.

Boulders also appear to have been carried with almost equal facility in different directions. The central part of the province is overspread with granite boulders from the south and west, and with greenstone and syenite boulders from the Cobequid hills on the north and north-west. The Cobequids, elevated about twelve hundred feet, have on their northern ridges sandstone blocks from the plain of Cumberland, to the north, and on their southern slopes granite boulders from the south. The valley of Cornwallis and Annapolis, extending nearly south-east and north-west, has granite boulders from its south side carried across to the north, and trap boulders from the north carried up the hills on the south. Great masses of debris have been swept out of the ravines of the Cobequids to the south, while the ruins of the conglomerates of the Pictou hills have been swept to the north and north-east. When all the exceptions are taken into the account, the preponderance of northern drift is by no means decided, and in many localities is not appreciable.

No formation has been recognized in Nova Scotia between the Drift and a series of red sandstones, to which the name of New Red Sandstone has been provisionally applied, and which, at one time, were confounded with the more extensive and important red sandstones of the Carboniferous system, which these new red beds unconformably overlie. In Nova Scotia the red sandstone is interstratified with great beds of trap, tufa, and trap conglomerate. In the neighboring island of Prince Edward, where the formation is largely developed, these indications of volcanic action are almost entirely absent.

Regarding, for reasons which I have endeavored to explain elsewhere, the red colors of these sandstones as an indirect consequence of volcanic action, and having observed the association of red sandstone and trap to occur under precisely the same conditions, in the new red sandstone and the lower carboniferous series in Nova Scotia, and believing such association to occur in rocks of almost every geological age,

I do not attach much value to similarity of mineral character, as identifying these rocks with the red sandstones of Connecticut and other parts of the eastern States. In Nova Scotia, however, it is certain that this formation is newer than the Carboniferous system, and has accommodated itself to the surface arrangements effected at the close of the latter period. It enters in bays and inlets into the Carboniferous valleys, and in Prince Edward Island it extends across the ends of the carboniferous troughs of Nova Scotia.

No fossils have been found in the New Red of Nova Scotia; but in Prince Edward Island the large reptile described by Dr. Leidy, and named *Bathygnathus Borealis*, and the occurrence of araucarian coniferous wood and fragments of plants resembling calamites, perhaps point to a Permian date.

4. *The Carboniferous System* has a thickness certainly exceeding 15,000 feet, but in its horizontal extent it is limited by older ranges of hills, which divide it into troughs and basins, and have occasioned great varieties of structure in its different parts.

(1.) In Nova Scotia the coal formation presents an upward extension, which, in so far as I am aware, is not developed on the same scale in other parts of America.* It consists of several thousand feet of red sandstones and shales, with occasional gray beds, and fossil plants identical with those of the coal formation; but without workable coal or marine limestones. This portion of the series I have named in former papers the "Upper, or Newer Coal Formation."

(2.) The productive coal measures underlying this newer coal formation, in consequence of the local causes previously referred to, present us with three different types of structure.

(*a*) In some instances, as at the North Joggins and Sydney, a great number of beds of coal alternate with stigmaria underclays, sandstones containing erect trees, and shales and limestones with *modiolae*, *fish-scales*, and *cypris*. In such localities very frequent alternations of condition and elevation have occurred, and have been accompanied by a profuse vegetable growth. It is in coal measures of this type that we find preserved those erect forests, remains and footprints of reptiles, land shells, and impressions of rain marks, that have been described

* In the discussion a similar set of beds was said to occur in the coal field of Pennsylvania.

by Sir C. Lyell, Mr. Brown, and the writer, in the proceedings of the geological society of London.

(*b*) In one coal field, that of Pictou, the whole of the coal has been accumulated in a few enormous seams, included in black shales nearly destitute of sandstones and erect trees. The thickest of these great seams has afforded the skull of the largest known carboniferous batrachian (*Baphetes Planiceps, Owen*).

The special conditions of the Pictou measures appear to have been occasioned by a contemporaneous gravel beach, which has separated the Albion Mines area from those parts of the surface in which sand was being deposited alternately with the coal. (For details, see Journal of Geological Society, 1853.)

(*c*) Other parts of the coal measures present the aspect of the upper member of the series, already referred to, or that of the next lower member, without any extensive development of coal and its accompaniments. This condition appears to prevail more extensively in New Brunswick than in Nova Scotia.

Similar varieties of surface, during the coal period, have been observed in Great Britain, and even in the great coal areas of the Western States.

(3.) Below the coal measures we usually find a great thickness of gray and red sandstones comparatively barren of coal plants, and corresponding to the millstone grit of England, and perhaps, in part, to the lower carboniferous conglomerates of the Appalachian and western coal fields.

(4.) The next member of the formation in descending order, is that to which the name of gypsiferous series has been given. It consists of red sandstones and red and green marls, with thick limestones usually filled with marine fossils, and numerous beds of gypsum. This formation appears to be wanting in the north of the Appalachian coal fields, but is largely represented by the lower carboniferous limestones and gypsum of the west and south. It is also deserving of remark, that in Nova Scotia, where these lower carboniferous beds approach the older rocky ridges, the limestones are diminished or even disappear, and are replaced by enormous beds of conglomerate marking the ancient beach, on which pebbles accumulated instead of the limestones that were deposited in the deeper water; presenting an analogy on the small scale to similar facts observed over larger surfaces in the United States.

(5.) Near these ancient shores, and at the very base of the carboniferous system, there occurs a peculiar pseudo coal formation, consisting of dark and often calcareous shales and sandstones with coal plants; in one instance, a bed of erect trees, underclays, and very thin coals. It is also characterized locally by the presence of great numbers of scales of fishes. This deposit, which belongs to the bays and estuaries of the older carboniferous sea, has been recognized in many localities, and has, in former times, caused much confusion by its being mistaken for the coal measures, and consequently leading to the belief that the latter underlie the gypsiferous beds.

To this part of the carboniferous system I refer the remarkable bituminous fish-bearing shales of the Albert Mine in New Brunswick, which have been so fertile of litigation and controversy.

Similar deposits have, no doubt, been produced at the margins of all the lower carboniferous seas, though the peculiar local features of Nova Scotia were probably especially favorable to their development.*

The peculiar characteristics of the gypsiferous member of the lower carboniferous series in Nova Scotia, I believe to be due to igneous action proceeding on the margins of limited sea basins, in which great deposits of coral and shell limestone were being accumulated.

The remarkable similarity of the coal flora of Nova Scotia to that of the southern and western States and of England, has been often noticed. The marine fauna seems to be more closely allied to that of western Europe than to that of America; most of the more abundant and characteristic species, as the Productus Martini and Scoticus Spirifer Glaber, Terebratula Elongata, Ceriopora Spongites, and Fenestella Membranacea, being common European forms, while, in so far as I have been able to ascertain, few of the common species in Nova Scotia are identical with those of the western States. This would accord with the indications of separation afforded by the absence of the limestone from intervening portions of the American coal areas, and by the Devonian elevations of land in Eastern Canada and New England.

5. *Devonian and Silurian Rocks.*—Before the Lower Carbon-

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* In the discussion Professor Rogers and Mr. Lesley described a very similar lower or false coal formation as occurring in Pennsylvania and the South.

iferous period, great igneous disturbances had occurred in the area under consideration, and all the previous sediments had been fractured and baked, and had been in part elevated into rocky ridges and islands in which volcanic action was still in progress in the Carboniferous period.

Nothing lithologically equivalent to the old red sandstone has been found, but there are some hard sandstones and grits of uncertain age apparently underlying the coal formation, which may belong to this horizon. The first fossiliferous rocks seen in descending order, are a series of slates and hard shales with abundance of fossils and frequent calcareous bands, and in one portion a bed of fossiliferous iron ore. The disturbances and metamorphoses of these rocks are so general that it is difficult in this region to ascertain clearly the order of superpositions; but there is a very great thickness of beds, and Professor Hall supposes them to range between the Clinton and Oriskany sandstone groups of New York. I have, in the present summer, made surveys of some of the more interesting portions of this district, and collected many new fossils, which, however, have not as yet been examined. In some parts of these rocks, the general facies of organic life is remarkably like that of the English Upper Ludlow.

The chronology of the igneous masses which have penetrated these beds, is only as yet beginning to be understood. In one of the fossiliferous beds of New Canaan, about the horizon of the Niagara group, there are pebbles of Amygdaloidal trap, and associated with other neighboring beds there are interstratified green stones. These are the oldest igneous rocks that I know in Nova Scotia. The whole mass is then cut by dykes of greenstone and porphyry, and penetrated by great masses of white granite with black mica, precisely like that of the eastern townships of Canada and many parts of New England, and probably about the same age. This granite has penetrated vertical bands of these rocks, melting the edges into gneiss, but crossing the beds without interfering with their strike. I ascertained for the first time in the past summer, the Devonian age of the granite of Nova Scotia, by observing its penetration of beds at least of Upper Silurian if not of Lower Devonian age; and collected many curious details in reference to the junction rocks, which I hope to throw into form for publication in the course of the winter. Lastly, the rocks of this group have been again penetrated by trappean rocks which have over-

flowed among the Lower carboniferous conglomerates; and probably, also, in a few instances by the trap of the New Red Sandstone.

The older Silurian rocks of Nova Scotia are represented by an enormous thickness of gray quartzite and clay slate in very thick bands, occasionally passing in the vicinity of the granitic masses which have been forced through them into mica, schist, and gneiss. These rocks have not afforded any fossils, and seem to be quite destitute of calcareous matter. They may, perhaps, be taken as representatives of the arenaceous and argillaceous members of the Lower Silurian series, without the limestones. They form, with the intrusive granite, a broad belt along the Atlantic coast of the province; and all igneous action appears to have ceased in this belt before the close of the Devonian period; a circumstance in which these rocks differ from the Upper Silurian and Devonian series already described.

The altered rocks which I have supposed to be Lower Silurian, are very destitute of calcareous, magnesian, and metallic minerals; with the single exception of iron pyrites. Those which appear to be Upper Silurian, on the contrary, contain much calcareous matter in thin bands, interstratified peroxide of iron with fossil shells, and large veins containing ferruginous dolomites, spathose iron, specular iron, and sulphurets of copper. We do not appear to have any representatives of the great Silurian limestones of the United States and Canada, though these occur on a large scale at no greater distance than the neighboring Province of New Brunswick.

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3. Geological Observations on the Pluto-volcanic Slope of the Sierra Madre along the Azimuth Boundary Line through North-west Sonora, made under the direction, and communicated with the permission of the United States Commissioner, Major W. H. Emory, U. S. A. By Arthur Schott, of Washington, D. C.

An air line drawn south-eastward from a point on the left bank of the Rio Colorado del Oeste, twenty miles below the mouth of the Gila to

the intersection of the meridian of 111° W. longitude from Greenwich, and the parallel 31° 20′ north latitude, comprises that western portion of the new boundary between the two Republics of the United States and Mexico, which was lately surveyed and established under the provisions of the so-called "Gadsden Treaty." Geographical terms for the same section of boundary line would be "Sonorian" or "Pimerian" line, for it runs through that north-western part of Sonora, which bears also the old Spanish name "Pimeria Alta," that is, "High Pimeria." A geodetic name for the same stretch of line would be "Azimuth line," because it intersects in an oblique direction from south-east towards north-west all the meridians and parallels falling in with it.

This line distinguishes itself from the eastern portion, which, running parallel to meridians and parallels of latitude, crosses north-eastern Sonora and Chihuahua, and finally terminates on the banks of the Bravo del Norte, a little above El Paso del Norte.

Our Azimuth line, then, takes its course, for its entire length, over the eastern slope of the basin of the California Gulf, following there the *divortia aquarum* between the Gila and those streams of North-western Sonora, which, by a south-westerly course, drain the adjacent country, finally shedding their water into the gulf just mentioned.

From one extremity of the line to the other, that is, from the heights of the Sierra del Pajarito, in the upper part of the Santa Cruz River valley, to the initial point on the banks of the Colorado, the line measures 233 miles (round number).

As to figures expressing the relative value of the hypsometrical features of the country, we shall have to be content with but approximative numbers, for circumstances have prevented actual measurements to that purpose.

An imaginary line drawn from the most elevated point of the Sierra del Pajarito about 200 or 300 yards south from the eastern terminus of the line to the initial point on the Colorado, exhibits a dip of about 22.1 feet to one mile, or an equivalent of 0.41 to 100. The point of elevation of the before-named Sierra is supposed to be 5,000 feet above the waters of the Colorado next to the initial point. Adding the difference between this point and the level of the sea, the elevation of the Sierra del Pajarito may be put down at 5,180 feet. This point does not seem to reach the pine region, which, in these latitudes, may be considered as from about 5,500 to 6,000 feet above the ocean.

The surface of North-west Sonora is characterized by a monotonous simplicity of features, and if it were not for close examination, even a more scrupulous observer would not be able to discover any thing but a mere dualism of diluvial drift and pluto-volcanic masses of rocks and mountains.

Along a very considerable portion of the line the former has covered those mountain ranges almost to their top, especially those approaching the valley of the Colorado. In reality the western section of our Azimuth line is running over what may properly be styled "a veiled country;" for of mountains only the crests and summits are to be seen, occasionally budding out from those desolate sand flats, which have buried the valley of the lower Colorado. This river winds its course through these forsaken barrens of drifting sand like a serpentine oasis, bordered by comparatively but narrow strips of timbered bottom-land.

The mountains ranging across that drift form the skeleton or frame of the geological edifice of the country, whilst the diluvial main may be looked on as its sinew and muscle. If we go further in the comparison, the alluvial deposits may be called the tegument or epidermis of the whole, which, to be sure, is most poorly represented. This natural deficiency, however, facilitates the observations of the geologist, who may look upon this country as if it were prepared and laid open for analytic investigation.

As its uppermost stratum we first take sight of the alluvials, of which very little is met with over the whole country except at the extremities of the line. The larger share of it appears in the bottom-lands of the Colorado; next to these come the regions of the higher mountains, whilst, strange to say, the plains are in this respect last in order.

The slopes, and generally the more or less inclined planes on the mountains, are sufficiently rugged and rough to form crevices, dells, and small valleys with obstructed outlets, which prevent entire deprivation of alluvial deposits, and form a condition of primary importance for the development of vegetable life, of which the almost naked plains, suffering under the sway of climatic severities and the devastating sweep of an almost continually moving sand, are a sad specimen.

Few traces of alluvial soil may be looked for at the so-called "playas" in the plains. These are depressions in the ground either sunk or washed out, and at the greatest vertical distance from the

summits of the mountains. Into these basins the aqueous deposits of the atmosphere, together with the lighter particles of the surrounding soil, are carried. In many cases the traveller may find here vegetation more developed, which then, however, consists more of a mass of equals than a diversity of genera and species.

Frequently such an apparently premature attempt of nature to promote vegetable life is sadly counterbalanced by the saline character of the soil, and then a prevalence of corresponding forms, as *Obione*, *Salsola*, *Salicornia*, and others analogous to them, take the place of *Algarobia*, *Prosopis*, or even of *Salix* in corresponding places.

The mainland filling up the levels between the various mountain ranges is constituted of a more or less uniform deposit of loose diluvial sand, a compound not essentially differing from the material the mountains are composed of. So we may call it, without hesitation, the detritus of the adjacent mountains, and the underlying firmer parts of the land. As to the mode of its being formed and distributed, we firmly believe it to be the residue of a once intermediate ocean, at the time a combining link of the Atlantic and Pacific Oceans.

Changes in the composition of this deposit certainly occur, but they appear to be more of a local character, and a certain uniformity pervades the whole. Fragments of quartz, mica, felspar, and of other crystalline and igneous rocks, together with particles of lime compose this almost unbounded stratum, forming a vast region of deserts between the eastern foot of the Californian cordilleras and the table-lands bordering the eastern shore of the Bravo del Norte. So we look upon it as a diluvial ocean a thousand times intersected and protruded by those gigantic walls, dykes, and reefs, which we know to be those mountain ranges already mentioned.

In the immediate vicinity of the latter, banks and isolated beds of pebbles are visible, the character of which is analogous to the lithological features of those mountain parts, whence they are derived. These pebbles, however, are not be confounded with other similar looking pebble banks, which appear occasionally right in the centre of those desert basins, especially along certain water beds, which at present may have served out their purpose, or may still be the dry channels for passing off rain-water currents.

Pebble beds of the first order are the result of the disintegrating agencies of the atmosphere upon the faces of the mountains, and are

deposited not far from the place whence they originated, whilst those of the second order seem to be the gatherings of an immense area, consisting of different pieces, removed from most diverse and often very remote geographical quarters. A wide-spreading medium must have gathered a compound of so heterogeneous constituents. In these sand beds we find, for instance, in loose pieces, limestones of different age and thrown together, where almost every geological era is represented by from carboniferous up to fresh-water forms. We also find here all kinds of opal, chalcedony, agate, jasper, slates, and other siliceous and silicified forms, breccias, conglomerates, either crystalline or amorphous. There are placed together silicified, agatized, or opalized fragments of wood, side by side with mere incrustations, either metamorphic or unchanged, and quite of late date. On another spot we may observe a semiopal, consisting entirely of fossil shells, the age of which is readily recognized by numerous Nummulites associated with them. With the hand we may take up an agate abounding in the neatest fragments of encrinitic or coralline forms, whilst our foot touches pieces of jasper or hornstone, in which, by means of a common glass lens, grain and texture of some coniferous wood can be perceived. Not uncommon are also large fragments of wood opal, also exhibiting ligneous texture, though with the traces of granulation entirely vanished away. Also glass opal or hyalite containing casts and marks of coralline forms; or pisolites, either unchanged or metamorphic, as if indicating the making of a loadstone.

The deserts on both sides of the Colorado and along the Gila abound in such pebble beds, surrounded by that same above-described uniform sand, by which they become occasionally entirely buried, or from under which they are redeemed again by the play of the atmospheric currents.

For the scientific observer, fragments of the mentioned character are the pearls of this vast terrestrial ocean, which must have formed once the bottom of an aqueous waste of the same dimensions, and under the sway of which these pebble beds must have been collected. Since the waters have receded from this area, another ocean of more substantial nature is waving here. Now the aerial currents are driving the shifting sand about, as it once moved with the waves of the ocean. At present only local alterations take place, moving the sand from one place to another. The level of these deserts must undoubtedly have been dis-

turbed since they were deposited. Besides the general declination of the western slope of the Sierra Madre towards the Gulf of California, an increased declination of stratum, round the base of intercepting mountains, is visible. This deviation from the angle of general ascent from the Colorado towards the Sierra Madre does not affect the mean angle of declination, which the diluvial main exhibits, but we may ascribe the former solely to the deposition of debris from the mountains.

The angle formed by the rising of the diluvial deposits and the base of the mountains in the Santa Cruz River valley, at the foot of the Sierra Santa Rita, was found to be $= 2.5°$.

The general ascent of country is a more essential proof of the upheaving of the country since the deposition of the quaternary strata or the diluvial drift. A line placed upon its plane, from the valley of the Colorado to that point of the Sierra del Pajarito where diluvial deposits cease, that is, about 1,100 feet below the highest point of elevation of said sierra, rises to about 3,900 feet, which makes 12.44 feet per mile, or an equivalent of 0.23 to 100.

Some valleys may exist heading on the slopes of the Sierra del Pajarito, through which diluvial deposits are rising still higher, but such exceptions do not affect the average of general ascent. The relative and absolute elevation to which this diluvial main rises in its approach to the Sierra Madre, forms a striking peculiarity in the features of the country. With a gradual ascent it furnishes a natural bridge almost over the whole height of those rocky mountains, the rugged crests of which otherwise would have remained inaccessible. Whilst offering, however, such an advantage to man's purposes on one side, it involves on the other side very serious evils. For it covers like a thick veil all that portion of country, which for its level character, or at least for its very small declivity, should form the proper field for those higher faculties of nature by which vegetable and subsequently animal life is developed. Instead of that, however, it now lies prostrated, a geological Sisyphus, having water at its base, and seeing water treasured up in the clouds without being able to receive and appropriate it. Even those few rains falling during a short season upon it are instantly swallowed up by the bottomless sand, leaving no marks of having been any way beneficial.

The few periodical water streams descending from the rugged mountain slopes, share the same fate with the scanty gatherings of the

clouds falling upon this drift land. Immediately after reaching it, they disappear from the surface, sinking to unknown depths, leaving marks of a rudimentary drainage only in the nearest vicinity of the mountains. Here bunches of shrubbery and trees border the usually dry water beds of the country. The blessings of water are lost upon these plains almost entirely, like ill-trusted alms in the bottomless pocket of an unworthy beggar.

The vegetation peculiar to the surface of this desert is much like that of corresponding localities on the east slope of the Sierra Madre. Besides a number of smaller and more inconspicuous forms, the *Larrea Mexicana*, *Fouquiera spinosa*, several *Obiones*, and other chenopodiaceous shrubs, and quite a number of papilionaceous and mimosaceous herbs, shrubs, and trees, together with various members of Cactaceæ occur through these desert regions, familiar to every traveller who has once passed over these plains.

We pointed above to the simple plan upon which nature has constructed the firmer parts of the country, that is, its rocky frame or skeleton. To come to the underlying strata upon which the diluvial deposits are placed, we have to step very deep at once, for constituents of the secondary era seem to be lacking wholly. Crystalline rocks of primary and transition age, metamorphic and unaltered, form the vast bed upon which the upper strata are placed. This foundation, however, does not form an even plane varying in its inclination, but its surface appears manifoldly broken, protruded, and turned up by eruptive masses, thus rising in many places above the level of the diluvial plains. The mighty sierras now forming the skeleton of our geological edifice have been shaped in the same way. In regard to their petrographic character we may distinguish them as pluto-volcanic.

With the hypsometric features of these mountain ranges, three important characteristics are connected. These are: 1. Parallelism among themselves, and also congruity of bearing to the range of the western coasts; 2. Articulation; and 3. Petrographic uniformity.

The parallelism among the various mountain ranges, and also the striking reference of their bearing to the western coast, is a fact much better known than the laws under which nature has effected it. Whether the linear extension of the longitudinal axis of these mountains was caused by a combined action of electro-magnetic forces and the tidal oscillations of the oceans, influenced and modified by isother-

mal, isoclinic, and isodynamic currents, we are not able to decide, and so we offer the following, though a mere theory founded upon observations made on the spot. Perhaps after the first onset of that peculiar reef, or dyke formation, probably a primary response of volcanic forces to the action of positive and negative electro-magnetism, a preliminary deposition of crystalline primary and transition rocks took place, followed by the precipitation of sedimentary strata. At this time igneous forces no doubt prevailed, and therefore the order of strata are throughout either of crystalline or of compact lava-like character.

In the course of those events the increasing volcanic debris became one of the agents to limit the heretofore free power of volcanic forces, promoting the counter actions of aqueous forces. Exogenous growth increased, whilst endogenous outcrops became confined. The waters, with their sediment, commenced locking up the volcanic fissures, whilst the fires had to seek other outlets, at the same time combining with their vertical vibrations horizontal oscillatory motions. To this we may ascribe the formation of those long reef and dyke-like mountain ranges, perhaps orographical meridians, which appear, however, often abruptly intercepted by cross valleys, dykes, or reefs, formed by different rocks. Such articulation may have been conditioned by the natural divisions of strata, that is to say, stratification, clearage, and lamination, influenced again by the aqueous interoceanic currents, which must have acted powerfully before all the walls separating the Pacific and Atlantic now were entirely closed. Considering such mode of formation, we cannot wonder at the diversified combination of plutonic, volcanic, and neptunic rocks, as they are in fact represented in the orographical system along our Azimuth line. We also cannot be surprised in perceiving the close petrographic relationship existing between all the different sierras, because they rose altogether from one pluto-volcanic focus, and were formed very likely surrounded by one general medium that was in a state of submersion.

To what degree our theory may agree with the geological data actually seen and observed, a special survey of the mountain ranges along our Azimuth line may show. Before entering, however, upon this subject, we propose a few remarks on some Spanish terms, which identify their objects with so much precision, that we should not like to part with them, lest we should be compelled to use insufficient circumlocutory words in their place.

We refer, then, to the following words: *Cordillera*, *Sierra*, *Cuchillo*, *Picacho*, *Puerto*, *Cañon*, *Loma*, *Mesa*, *Ciénaga*, *Charco*, and *Tinaja*.

*Cordillera* means a long mountain range composed of several parallel running integrating ranges, which, however, occasionally can be intersected by cross valleys and passes. The characteristic of the term is, that a cordillera is formed by two or more ranges constituting one orographical body, as a cord consists of several strings twisted together. Cordillera and cord are formed upon one root.

*Sierra* mèans a saw, or a mountain range with a serrate crest, and of a reef, dyke, or wall-shape. The cross diameter of both the Sierra and the Cordillera is generally very small, compared with their longitudinal axis.

*Cuchilla* is a branch or outrunner of a sierra, partaking in its physiography with the latter. Its sharp-edged crest probably caused the name Cuchilla, which stands upon the same root with cuchillo, signifying knife.

*Picacho* signifies a sharp, tapering, or obelisk-like peak, with the cross and long diameter in a similar disproportion as for a Sierra or Cordillera.

*Puerto*, a gate, gap, or port. Its topographical meaning here is, an open pass over or through a mountain ridge, not of any length, as in, for instance, a causeway or *cañon*.

*Cañon* is a mountain pass or defilée with no outlets on either side.

*Loma* is a long narrow mountain or hill-ridge, with a level horizon; Lomita is but the diminutive form of it.

*Mesa table* means here table-mountain or table-ridge, the top of which is of a wide horizontal extent; mesilla is the same on a smaller scale.

*Mal páis*. Bad land or *mauvais terre* of the French. In Sonora it is exclusively applied to mesas, lomas, or any table-land constituted of large beds of igneous rock mostly compact or vesicular black trap.

*Ciénaga* is a valley or mountain basin with an obstructed outlet and hemmed in all round by hills or mountains; thus the ciénaga abounds in miry or swampy places.

*Charco*, a water-pool found usually in lower and level places. They are formed either by the decay of rocks or by washing out of beds of clay.

*Tinaja*, a water-hole in solid rock, and usually met with in the crevices and ravines of rocky mountains. The word applies originally to an earthen jar not glazed so as to allow exudation of the contents, by which means the water inside remains cool.

After this we may proceed with a review of the various sierras, which, by following our Azimuth line from south-east to north-west, we shall have to cross.

The eastern terminus of our Azimuth line on the north slope of the Sierra del Pajarito shows crystalline transition rock either metamorphic or unchanged, and also trachytic and porphyritic strata or else metamorphic forms of granite and syenite. Some of the more elevated parts exhibit very rough masses of a cellular texture, whilst the lower are more solid and smooth in the water beds, even polished. The color is dull red or subdued light pink. These rocks also abound in crystals of glassy felspar, and occasionally particles of augite, thus answering to the frequent occurrence of syenitic granite. The foot of this sierra is on the north side washed by a small mountain stream, which is, however, during the most part of the season dry, with the exception of few *charcos* and *tinajas*, which are formed in solid masses of rock. The bed of this little stream is lined with a singular formation, apparently of later age. At first sight we looked upon it as if it were fresh-water lime overlying or placed alternately with a certain volcanic breccia, the matrix of which is much like the just mentioned formation. Perhaps it is really a volcanic mortar, in which large and angular fragments of amygdaloid and porphyritic rocks are imbedded. This same compound forms throughout the lower portion of the before-mentioned valley one solid cemented mass, hemming in *cañon*-like the course of a torrent between vertical walls of an average height of 30 to 50 feet. The color of these masses is a brownish yellow, with an ash gray crust. The latter looks as if it were the result of a process of calcination. In some spots where this crust was found decaying out, a marl-like, mealy powder, like chalk, could be scratched out from the inside. Upon further investigation, also, trappitic, amygdaloid, and porphyritic rocks, at whatever elevation they had been taken up, were found with a cream or mortar-like paste of carbonate of lime adhering to them or filling the otherwise empty cavities of vesicular or else porous, igneous rocks. From this we conclude that carbonate of lime, in some form, must have been an ingredient in the formation of this strata of

later date. In the east slope of the Sierra del Pajarito, in a valley called "Los Nogales" (the walnuts), similar strata border the course of a little stream on one side forming a continuing winding low bank or terrace from six to ten feet high, exhibiting horizontal stratification, and on the other side covering, to some extent, the slopes of the surrounding mountains and hills, constituted of crystalline transition rocks. On these hill-sides these apparent limestone strata form shelve-like beds coating over those rocks of higher age. These shelves are dipping towards the valley. Their texture shows plainly lamination. Further east from Los Nogales, that is, in the Santa Cruz River valley, the same formation seems to be still more boldly developed. To the south and towards the south-easternmost link, the same Cordillera that is on the strike side of the Sierra Santa Barbara, and also still further down into Sonora, strata of the same nature abound through all the valleys drained by running water.

The volcanic breccia, occurring also and in abundance in most of those water-leading valleys and ravines of the Sierra del Pajarito, rises from forty to fifty feet under an angle from upwards of 45° to vertical walls. Some pieces of this mass were tried, heated in a large log fire, and then thrown into cold water, upon which they showed much effervescence, but without going to pieces.

To the north and north-west of this mountain range, with its bearing from east to west, the Sierra Janos is rising up in bold terraces of a dark-red brown amygdaloid trap, or trap-porphyry. The broadest terraces are along its lower regions. The edge of each of these gigantic shelves is bordered with outstanding rocks, reefs, dykes, pinnacles, cliffs, in the most fantastic manner. The level of the terraces declines towards the main body of the sierra; thus a series of parallel running lateral sierras are formed. The most elevated part, the central stock, forms a huge table-block, exhibiting on its south and west side distinct marks of stratification, cleavage, and lamination. These marks intersect each other vertically, and so the whole mass resembles a veritable mason-work, the rectilinear fissures of which are visible at a distance of from ten to fifteen miles. The vernacular name, "Janos," has thus as little to do with the physiography of these mountains, as Pajarito has with the former. The one means a little bird, the other a certain shrub. The latter may have some physical reference to the sierra to which this name is fixed. Janos signifies in the Papago language a species

of chilopsis, which grows in superabundance, in analogous localities, all over those regions. The striking resemblance of the central block of this sierra to mason-work, would certainly justify the repetition of the more appropriate name, "de los ladrillos," (of the bricks,) for it agrees in its appearance with the description of a portion of the Peruvian volcano Pichincha, given by Humboldt. A similar petrographic phenomenon is mentioned there, with the only difference, that the rock on the Peruvian mountain consists of some kind of pitchstone-cleaving ore, laminated in its vertical slabs or layers. This makes the strata, at a distance, appear like mason-work, and gave rise to the name, "de los ladrillos," among the inhabitants of Quito.

On the northern foot of the Sierra Janos, another group, though upon the same longitudinal axis, is annexed, forming clearly with both the former one body or one sierra, ranging south-east and north-west, and bordering the left bank of the Santa Cruz River. The three links of this sierra have a common dip and strike; the former being in an easterly direction, and on the sierras Janos and Atascosa from 5° upwards to 25°; the latter faces the westerly regions, and falls off vertically, in bold terraces. The petrographic character of the Sierra Atascosa seems to fall close together with that of the Janos, and as they are also so closely connected, they may be considered as twins. The mountain range formed of these three sierras terminates on the north-western slope of the latter, where a valley intersects an immediate connection with the Sierra del Babuquibari in the north-west. This valley, communicating on the east side only by a narrow pass with the valley of the Santa Cruz River, is one of those intersections separating the cordilleras and sierras of the country into articulated mountain bodies. The valley itself bears the name of Aribac, or Aribaca, from a deserted Mexican settlement, situated there. Good and constant spring water is found here, which may cause sometime the reëstablishment of the rancho, after security against the marauding Apaches shall be realized. The name "Aribac" is undoubtedly of Papago origin, though we could not ascertain its meaning. The slope of the Sierra Atascosa, towards this valley, is formed by igneous rocks and peaks, towering up in the most odd and grotesque shape. This locality also bears the name "Mal pais," which it certainly deserves, considering the rugged character of this slope of igneous rocks. Atascosa, the name referring to the whole of this sierra, means, "miry,"

or "stick in the mire." We know not whether this name really points to the petrographic character of these mountains, which is indeed most likely, because they appear as if they had once risen out of a boiling volcanic pool during some chaotic era.

The absolute height of these three sierras above the level of the Santa Cruz River seems to be pretty nearly equal, though the highest points of the Sierra Janos looked to me as if they commanded all others.

All round the Sierra del Pajarito smaller and larger springs abound, but their course is more or less concealed, and it wants, therefore, the expert eye of an Indian, Mexican, or hunter to find them, especially during the latter part of the dry season, that is, from April to a part of July. On all sides of this sierra, from its base to the summit, vegetation is well developed. All the slopes and valleys abound in good grazing, and a dense growth of shrubbery and trees covers the rough surface of those mighty slopes, cut up into thousands of little valleys, ravines, and crevices. Three or four different evergreen oaks are met with on this sierra, among them the "vellote" of the Sonorians, with sweet, eatable acorns. A species of cedar appears in the more elevated parts, which, however, does not seem to reach the pine region fully. A few years ago the fauna of this country was characterized by hundreds of heads of wild cattle roaming through these grassy valleys, but they have since been exterminated by the restless hunter. According to its physiographical features the Sierra del Pajarito partakes in the good things of the Sierra di Santa Cruz, and all the various links of those sierras belonging to one system with the Sierra Madre, farther east. Even in respect to metals the Sierra del Pajarito is not left behind. Whilst in camp at "Los Nogales," Major W. H. Emory, United States Commissioner, received several fine pieces of very promising looking silver ore, obtained in the immediate neighborhood of that place.

On the top of the Sierra del Pajarito we find ourselves on the vertex of a dividing ridge, sending water by the Santa Cruz River north-west to the Gila, and south-west towards Presidio del Altar, and other places in that direction. We have dwelt, intentionally, longer upon the features of this sierra, because of its being hypsometrically and geognostically best developed among all the sierras coming to sight hence west towards the Gulf of California.

The Sierra del Pajarito forms a type and a standard for the comparative review of the rest.

Viewing the country towards the gulf from the western peaks of the Sierra del Pajarito, a wild and rugged net of mountains lies spread out. Notwithstanding their being constituted of similar crystalline and transition rocks, they do not rise so high as the former, but being in long ridges, closely packed together, and dipping uniformly towards the south-west, they form a kind of mountain relief, the grandeur of which lies more in its uniform wide extension, than in the peculiarity of shape.

At a distance of about sixteen miles another sierra of igneous rocks is visible. Between this and the last one we spoke of very little drift is met with, and, where it appears, we find it always confined to valleys, until we come half way between both sierras. Here, by the action of water currents, *mesas* and *lomas* have been formed, rising to the height of from 40 to 50 feet.

The waters running from here south-east soon join those coming from the east slope of the Sierra Escondida, a small distance south of the line, near a place where in a hidden deep cleft between igneous amygdaloid rocks permanent water is found. This, however, seems not to be a spring, but a *tinaja* supplied by the trickling down of water from *tinajas* situated above. The character of this place caused the name "Escondida," meaning here the concealed water, but it is applied to the whole sierra. This range, according to its orography, is but a gigantic volcanic dyke, here towering up with an isolated rugged crest of igneous rocks (amygdaloid and porphyritic), and there intercepted or overlaid by overthrown and contorted crystalline strata of a coarse-grained felspathic sienite, mostly metamorphous. The cross diameter of this sierra, where it is intersected by our Azimuth line, exceeds scarcely one mile in length. It is, however, on both sides bordered by the quaquaversal upheavings of those crystalline beds just mentioned.

Near the spot, where three singularly looking peaks mark the locality of that hidden *tinaja*, we visited the top of the sierra, which, in barrenness, far surpasses the Sierras Pajarito, Janos, and Atascosa. Some parts of the table-like planes and also the slopes are covered with large patches of white chalcedony in the shape of scoria. The southern part of this sierra exhibits a more horizontal arrangement, as

if its disposition had been made in a state of submersion. Here black vesicular trap prevails, forming ridges and cross banks, and further below, *lomas* and *mesas*. The topography of the country seems to indicate here the junction and gathering-place of a number of mountain streams and torrents.

The boundary line crossing the Sierra Escondida, passes over its crest a little to the north of a conspicuous peak, the highest point of the whole range. This peak, belonging to the State of Sonora, received, therefore, the boundary name "El Cerro di Sonora."

A group of low granitic hills, a western upheaval of the Sierra Escondida, furnishes, near the line, several water places well known to the natives of the country, the Papago Indians, Mexicans, and Apaches. Some of them are mere *tinajas* and *charcos*, others seem to be real springs. They are liable to become sometimes dry before the setting in of the rainy season. A heavy hail and thunder-storm our party encountered here occasioned the name "del granizo" for this little mountain group. This same meteoric incident furnished a proof how little time it requires to submerge all the adjacent valleys under the most terrible sweep of mountain torrents. Our camp at the time was near the head of a ravine, and, notwithstanding the short range of the latter, after an elapse of not more than five minutes hail and rain had created a water current of at least five feet average depth, thus instantly filling up the whole rocky bed to its top. The granite found on this sierrita is white, very coarse grained, and richly charged with large plates of silvery mica. It is also occasionally impregnated with an addition of hornblende.

A broad, flat valley nine miles wide separates the Sierras Escondida and Granizo from the Sierra Verde, which is nothing more nor less than a southern spur or branch of the Sierra Babuquíbari to the north of the line. The plains bordering the various dry water beds of this valley are well furnished with good grass, and seem to be the resort of plenty of game. The water beds themselves are bordered by a remarkably rich growth of oak and hackberry (Altis). The Sierra Verde, so called from the beautiful verdure encountered in the shelter of its rugged and clefted valleys, seems to be formed entirely by the same felspathic granite, which was mentioned for the east slope of the Sierra Escondida. The dip and strike face East and West. The width of the sierra is scarcely more than one mile, and no petrographic

novelties are here met with. Its longitudinal axis ranges south-east and north-west, where it joins the bold igneous walls of the Sierra Babuquíbari, at a distance of about fifteen miles hence. The entire length of the Sierra Verde scarcely exceeds twenty miles. Round its southern end some trappitic hills and mounds cross out from the diluvial main. At the same locality, right under the steep side of the sierra, a springs finds its way to the surface, fitting this place for a general camping-ground for roaming Indians or travelling Mexicans. The locality itself is generally known to the inhabitants of the country under the name "Pozo Verde," (green well).

Almost due north from the surveying station established upon the crest of the Sierra Verde the *Picacho* of the Sierra Babuquíbari is situated. This is one of those orographical phenomena of the country, the singularity of which could not fail to raise the attention of the red man. The Papago Indians in fact consider this large mountain obelisk their palladium, where they take refuge in times of famine, drought, war, or any other general calamity. "Babuquíbari," we were told, signifies in the language of these Indians, "water on the mountain," and is formed by "babu" water and "ari" rock or mountain.

The increased height of the main body of this sierra, and especially the bold offset of a large obelisk of one solid mass on the top of the former, exercise, very probably, an increased power of attraction upon the clouds, which, therefore, gather more copiously round its head. At the same time the more inaccessible recesses of the sierra aid the securing of welcome water stores in those higher regions.

Viewing the country westward from the heights of the Sierra Verde another wide plain is visible, which, at a distance of from twelve to fifteen miles, is intersected by another mountain range, traversing the country in that invariable bearing, south-east and north-west. The eastern half of this intermediate plain seems to be more favorable to the development of vegetation than the western part, which, especially in its lower portions, is entirely deprived of floral life. The eastern part abounds in grass and dense brush-work, besides a considerable growth of mosquito-wood, whilst the western seems to have been at first divested of all vegetables by the destroying tooth of small troglodytic quadrupeds. It is a singular fact that both parts of this plain, a short time before our visit there, had been equally benefited by copious rain, and notwithstanding the western half had remained a naked, barren

flat. Through the thickets of the slope under the Sierra Verde we saw flocks of black-tailed deer, which seem to have here their western limits, whilst, on the western barren half, numbers of shy antelopes freely ranged over the open level. No doubt the physiography of the country commences here to change to its disadvantage, of which we shall see more after reaching the next mountain range; which, unlike the others passed until now, is but a short detached group of hills and mountains budding out from the diluvial main like an island. Though of much smaller extent, it still presents the same petrographic character by being a binary compound of igneous and crystalline rocks, the latter taking, we believe, the larger portion. On the east slope similar felspathic granite rocks in a decayed somewhat metamorphic state occur, whilst the west slope exhibits again that quartzose quaternary granite we spoke of at the Sierrita del Granizo. The centre part, the spine of the whole, is formed by amygdaloid and porphyritic masses here and there overlaid or otherwise concealed by crystalline strata, which have not been thoroughly protruded by the former. The north part of this sierra is occupied by the highest peak, rising solitary above the others. This fall to the north of the boundary line received the name "Cerro de la Union," which was also applied to the whole group. From the surveying station established in the *puerto* of the Sierra de la Union, we look east and west as from a physiographical dividing ridge upon the surrounding country.

Through the part just passed over, mountains and mountain stretches prevailed, leaving but a small share for the distribution of diluvial deposits, but hence westward levels and plains, formed by drifting sand, increase and consequently sterility and desolation become a ruling feature. This change seems to be caused by the gradual submersion of the mountain ranges under the level of the diluvial main. Thus losing width and length, sierras appear now but as interrupted detached parts of mountain ranges, the mutual connection of which only can be guessed at by their general geographical bearing. Cordilleras and sierras, as we shall see afterwards, are of a more loose texture from the increased interspersion of drift land. Whilst the country to the east resembles an aggregate of narrow straits bordered by long mountain reefs, the land ahead begins to widen and become like the outside of a shallow coast, studded all over with small rocky islands and cliffs, the scattered pieces of reefs and dykes. The more open country

is now influenced by the climate of the gulf coast. Certain plants, apparently real desert forms, appear first on the west slope of the Sierra de la Union; among them two leguminous trees, the *Palo Verde* and *Palo di Hierro* of the Mexican. We notice here, also, a predominance of cacti, which we may not improperly call the corals and algae of the aerial ocean.

The boundary line crosses, at a distance of nearly seventeen miles of desert, a comparatively narrow and low sierra chiefly constituted by porphyritic and amygdaloid rocks. The point of crossing is marked by a natural monument, a fork formed by two bold vertically rising horns of solid rock. The sierra itself is a northerly continuation of a cordillera with the name Lóbota. The word seems to belong to the language of the Papago Indians, who have several large settlements in this vicinity; the meaning of the word, however, did not become known to us. About three quarters of a mile south from the line, a *cañon* intersects the Sierra de los Linderos, through which the western side is reached without much difficulty. In this natural opening a great deal of crystalline, primary, and transition rock is developed, though the igneous masses maintain at the same time their supremacy. The name, "de los Linderos," was given to this sierra on account of those two cliffs forming a fork, through which the line passes, and bringing, one to the American, the other to the Mexican side. Lindero, in Spanish, means a boundary or a landmark, and therefore the application of this name here.

Another desert plain, from seventeen to eighteen miles wide, separates the Sierra de los Linderos from that of de la Nariz. Though both of these mountain ranges appear, petrographically, very near related, there exists one striking difference between them. The former at least, at our point of crossing, is a real volcanic dyke at its base, in some places bordered by upheaved crystalline strata. Its crest of igneous masses, forced through a body of fantastically contorted, partly shattered walls and dykes of volcanic rocks, resembles a group of Titans, turned into stone whilst they were in the very act of assailing the heavens. On the other hand, the Sierra de la Nariz, consisting, also, of nothing but igneous masses, (trappitic and porphyritic,) appears more to be the result of simple, less intense, uni-lateral upheaving. Its crest, comparatively even, is nothing but the turned up edge of a vast bed of volcanic or volcanized rock, dipping in a north-easterly direction,

whilst its strike at an absolute height of from 200 to 400 feet is turned west.

The surface of its easterly slope is covered by a thick layer of loose boulders, of a black vesicular trap. On the strike stratification is visible even from some distance, the layers being of various thicknesses, from five feet and less up to twenty and twenty-five feet. The Sierra de la Nariz ranges in a slightly curved line, from south-east towards north-west, where, at a distance of about eight miles, it is connected with the Sierra del Ajo, of which it appears to be but a south-eastern ray. Next to the point of connection between the two sierras, that of the de la Nariz is divided into two subparallel running branches of which the westernmost is only short, not exceeding ten miles in length, whilst the eastern range continues for twenty miles. Near the intersection of the boundary line, a little to the north, quite a depression occurs, where the sierra hardly reaches fifty feet in height. In this vicinity it is also traversed by two open passes, the bottom of which is almost upon a level with the diluvial main. The vernacular name of this sierra is Spanish, and means "nose;" the reason of its application was left unknown to us.

To the north of the Sierra de la Nariz another one is visible, at a distance of about fifteen miles, which is the width of the intermediate level valley. It seems to be perfectly analogous in its petrographic character to the one of de la Nariz, having dip, strike, and stratification the same with the latter. Both these sierras are accompanied by a number of little trap-mounds, reaching out at the base of the former, from the level of the valley, not rising, however, higher than from thirty to forty feet. Springs are not to be found in any of these mountain ranges. The few animals of the wilds, also the Indians and travellers, depend here entirely on *charcos*. As we at the time were fortunate enough to encounter such water places, in the neighborhood of this sierra, where we least expected them, the name "Laguna de la Esperanza" (lagoon of hope), was given to it. This range seems to be, also, an eastern link of the Sierra del Ajo.

From the heights of the Sierra de la Nariz to the north-west, a bold and high range stands in sight. It appears more like a node or a compound of sierras, a forced consolidation of various branches. This mountain group bears the Spanish name, del Ajo, which means "a garlic." The reason for this singular name is based, as we were informed, upon

the morphological features of the sierra. Though probably constituted of similar volcanic rocks like the others, its structure is different. As it is seen from south-west, from the Liénagas of Sonoyta, a huge centre block, of either metamorphic, or more probably, volcanic or volcanized stratified rocks, is observed on the strike side to be in its middle penetrated from below by rocks, which, as it seems, are lithologically alike, but of columnar structure. The whole body is hereby divided into two nearly equal portions. The aspect of this, and the before-mentioned sierras, is indeed very singular, and impressed upon us the idea of geological mummies, on which metamorphism chemically and mechanically produced such thorough changes, altering their lithological characters, but preserving their morphological features. On the sides and at the base of this sierra, quite a number of volcanic peaks are towering up, one superviewing the other, but undoubtedly, all together, standing upon one and the same volcanic focus, however detached their situation above ground may appear. Thus the main body of the Sierra del Ajo resembles in its shape the bulbous head of a garlic. A comparison like this, though rather keen and parabolic, may be otherwise justified, as it implies, at the same time, the endogenous growth of both the sierra and the garlic head.

The mountain range of del Ajo also forms a sort of a dividing ridge between the waters of Sonoyta, running in a westerly direction towards the Gulf of California, and those waters turning in an easterly direction from the slopes of the Sierras de la Nariz, and afterwards taking, also, a south-westerly course.

On the westerly foot of the Sierra del Ajo, a wide valley is spread out, which, being hemmed in all round by mountain ranges, and having but one obstructed outlet, is what the Spanish call a "*ciénaga.*" Its southern border is formed by the Sierra Guehibabi, which is a Papago name of no known meaning. As the sierras just before spoken of strike the eye by their dark-brown, almost black color, the sierras to the south and west are constituted of metamorphic crystalline rocks with prevailing felspar. The color of these mountains, especially under the rays of a Sonorian sun, is a glaring white. Thus we find the often repeated, and somewhat fabulous sounding stories of general travellers well founded, when they talk, for instance, about the pass between a white and a black mountain, or something of that kind. On the foot of the eastern end of the Sierra Guehibabi, near the old mission of

Sonoyta, chloritic slates and greenstone come to sight. They appear, however, to be but local, and a branch of the same sierra ranging due north shows throughout that same white or light-colored felspathic crystalline rock. This branch being lowest in elevation and but short, until it is absorbed by the western outrunners of the Sierra del Ajo, was named Sierrita di Sonoyta. The eastern part of the *ciénaga* is open for travellers to Presidio di Altar. There the dividing ridge is nothing but a slight swell of the diluvial plain.

Besides the abundance of deep *charcos* and lagoons through its lower portion, this *ciénaga* is blessed with the origin of a small river, fed at its very outset by a large number of little springs, undoubtedly rising from a very great depth. Their water is beautiful, clear, of a bluish hue, of somewhat high temperature, and slightly brackish. Notwithstanding the rich supply by which the little river of Sonoyta is nourished at its birth, it is not able to remain a running stream. Before reaching a mile it disappears under ground, and regains daylight several times. The water, however, is constant enough to justify a settlement in its vicinity. The Roman church had once established one of her missions (Pimeria Alta) in this remote and desolate quarter of Sonora. This well intended establishment, however, like the little river of Sonoyta, did not show much vitality. Some poor fragments of miserable walls are the whole that is left, by which to recognize the spot near the outlet of the valley. This is occupied now by a group of a few Mexican and Indian huts, the inhabitants of which irrigate some tillable ground. The proportion of the latter is very small, and scarcely enough to satisfy fifty Papaga families.

In the physiography of the country the Sierra del Ajo, forming the north-eastern corner of the Ciénaga di Sonoyta, seems to be a remarkable monument, which establishes the real boundary between the coast and the interior. It is also in the north-western portion of the same that rich argentiferous and auriferous copper ores abound, containing, as it is said, sufficient gold and silver to defray the expenses of mining and separating the copper. These ores were rediscovered some years ago, and are worked now by a Californian mining association, called the "Arizona Company." This company, besides exploring first the stretch hence direct to the Gila River, opened also with considerable expense and labor a road through the mountain passes,

and provided, by means of artificial tanks, for the preservation of rain-water, which annually falls upon those regions.

Following the bed of the river of Sonoyta, a narrow pass leads without any difficulty into another *ciénaga,* which, being not so well watered as the one of Sonoyta, bears again the common desert character. Its diametrical extension is about like the former, and may be stated to have a width of fifteen miles each way. The Sonoyta stream winds its course through it, but forms only in the upper half, in two or three places, small shallow ponds, where, during the dry season, water may be got by digging.

Mountain and hill ranges, formed by the same felspathic crystalline rocks, border this *ciénaga* all round. The more open west end is limited by a swell of the diluvial beds, leaving but one opening for the occasional surplus of water from the Sonoyta River. This *ciénaga,* which may be called "Quitobaquita," partakes still more of the physiography of the California desert.

Quitobaquita signifies, in the Papago language, a small mountain gap or pass, which in reality is formed here by low mountain ridges, spurs of the Sierra del Ajo, Di Quitobaquita, and Guehibabi. Upon the rising ground on the west end of this *ciénaga* a wealthy Mexican established a cattle rancho. The inhabitants of the latter depend on spring water, which flows in abundance from some twelve to fifteen small springs, all rising in one line upon a bank which apparently has been formed by the same material they themselves had precipitated. The substance itself seems to be some form of carbonate of lime. The water of these springs resembles fully, in appearance and mode of issue, that of Sonoyta, and we shall not be mistaken in placing the phenomenon of both upon one physical base, and considering them to be mineral or thermal springs.

Leaving Quitobaquita the line passes over a broad ridge, dipping east and west, and forming a kind of yoke (jugum) between the Sierra of Quitobaquita and a mountain group to the south called "Los Cerros de la Salada." Here all round crystalline felspathic rocks prevail. The structure of these *cerros* indicates a general geognostical disturbance, under which these hills and mounds have been grouped together. They are of different absolute height, and their rocky parts are very much interspersed or covered with debris. In general the

entire arrangement and ranging of the sierras between this place and Sonoyta exhibits some deviation from the established rule of parallelism among all the sierras of north-western Sonora. The mountain ranges of Quitobaquita, Del Ajo, and Guehibabi appear like three gigantic rows of waves, which, after overreaching one another in discharging their contents, form a net of irregularly ranging mountain marshes.

The water of the little river of Sonoyta leaves its course above ground for the last time at Quitobaquita to follow its terrestrial course. Two miles below, on the south-east side of the Cerros de la Salada, fresh drinking water can be got by digging from two to three feet deep in the bed of the river. One mile further below, the water of the same stream is so exceedingly saline that not even starving mules will touch it. This salt water occasioned the name de la Salada, which is also applied to the mountain group placed next to it. Hence the country opens entirely in a southerly direction towards the coast, leaving free sight to a pretty bold but entirely isolated sierra of considerable height, which is named "Pinecate." This singular name, signifying a beetle, must probably have originated from some particular occurrence, for we have not been able to find out any reference the name could have to any peculiarity of these mountains. This sierra, about twenty-five miles distant from the line, is, for want of water, almost entirely inaccessible. It is renowned, however, through all Sonora, for its wonderful and inexhaustible layers of rock salt. It is stated that this precious material is stored up there in immense masses, and arranged under a diversity of strata varying in all tints and colors. The group of the Cerros de la Salada is most probably connected with the salt region of Pinecate.

After passing the Salada mountains a wide waterless desert stretches out, studded with a number of isolated little peaks and mounds of every size and shape, partly formed by our well-known felspathic rocks, and partly by igneous masses either trappitic, amygdaloid, or porphyritic. Southward this desert is bounded by low ridges and gradual risings of the diluvial main, and to the north and west by bold sierras alternately constituted of the before-mentioned volcanic and plutonic rocks. Westwards, at a distance of about thirty-five miles, a very rugged cordillera called Sierra del Tule limits this desert, but only to connect it by an intermediate narrow strip of desert with the great Colorado waste. Few insects and reptiles, fewer birds, and still fewer quadrupeds scan-

tily animate these forsaken regions, which death seems to hold under his seal. No reliable water-places invite the traveller on these plains to a short stop so as to recreate himself and his worn-out animals. "Either fly or die!" stands before his mind, and even animals have the same warning, and so both man and animal exert their last strength to escape. A number of graves and skeletons and numberless dried up carcasses along this road can witness how many lives have failed in reaching the other side.

The western portion of the desert, between the Salada peaks and the Sierra del Tule, rises towards the latter. This rise, together with an immense bed of black vesicular trap, commences in the playas of those *charcos*, in the centre of the plains, where, a short time after a rain, water may be found. Hence little black mounds and small white peaks increase in number, acquiring, gradually, a more elongated shape, and turning finally into low and abrupt sierritas. On drawing nearer towards the Sierra del Tule, the sierritas increase in size and number, and form parallel outworks of the Sierra Tule itself.

The huge crest-masses of this range appear like the white and black heads of long ocean waves, suddenly arrested and crystallized when in the midst of a chaotic uproar, thus telling their mythic tales of past eras. The upheaving forces employed in the formation of this sierra, or rather cordillera, left one uniform but nevertheless very eloquent mark on the face of these mountains. The combination of rocks is also very simple, consisting only of those black and white masses, in one place pressed closely together, and in another towering up, each one taking a separate shoot. Dip, strike, cleavage, and lamination are here obscure and contorted or overthrown, and in another spot distinct enough to be traced from two to three miles distance. Thus we are able to mark one mountain block formed by the upheaved corner or edge of one solid bed of felspathic sienite, or granite, changed into granitic or sienitic lava, or into regular trachyte, containing quite an amount of large crystals of glassy felspar. A singular aspect, too, is presented here, by mountains of such crystalline rocks, which had protruded an old bed of vesicular trap, and stand now like giants, wrapped up in the torn garments of dwarfs, now hanging in rags round their body. The morphological features of these gigantic stonewalls have much resemblance to the ice formations of the arctic oceans. Similar causes effected similar results in the formation and crystallization on

one hand of pluto-volcanic rocks, and on the other of consolidated aqueous masses. They both appear, in outline, perfectly alike, and so we observe here icefields, hummocks, packs, icebergs, and there, analogous in shape, beds of trappitic lava, contorted peaks and pinnacles of porphyritic and amygdaloid rocks, or the turned up edges of gigantic beds of metamorphic rocks, or the bell-shaped domes of trachyte, all together forced upon each other, broken, crushed, shattered, and formed over again. Both the icy and the rocky bodies float, each one half submerged, upon an ocean, the one upon the salt waters, the other upon the residue of a diluvial sea. The moving medium of both is also somewhat the same, and adequate to the masses to be worked upon. There are the oscillatory motions of the sea with one, and the vibrations of the earth's crust with the other.

Much like the Sierra del Tule is the one de las Tinajas Altas, deserving, also, like the former, rather the name cordillera. The petrographic features are almost the same, and there cannot be much doubt but that both are placed upon one base. The intermediate flats separating them are of the same repeatedly mentioned desert character. The same deadlike silence, and the same dreary desolation pervade this desert-chamber placed between the two sierras.

The mountain range of de las Tinajas Altas is the last one traversing North-western Sonora towards the Colorado del Oeste. From its crest but a few little peaks, reefs, and rocks are visible, forming the eastern coast of the Colorado desert, which, after this, becomes perfectly open. These orographical studs are in all probability but the crests and peaks of a submerged sierra, deeply overlaid by that same drift, which extends from here to the foot of the Californian Cordilleras, a distance of 130 to 140 miles. The direct distance from the Sierra de las Pinajas Altas to the nearest point of the Colorado may be set at forty-five miles.

One sheet of desert then stretches down to the banks of this river, unbroken, and only traversed in its middle by a light swell of the same forsaken sand. We incline to consider this rising in the midst of the desert, as the half-grown bud of an underground sierra, waiting only for nature's command to rise over the surface.

After a closer examination of the geological relief of North-western Sonora, we arrive at the conclusion, that such a state of country cannot be considered as having reached its physiographical point of cul-

mination, because its far larger portion lies buried under a thick veil, not only concealed from man's eye, but also inaccessible to those more beneficent agencies of creation, which alone could develope organic life upon the surface of this vast area, at present condemned to but a terrestrial existence.

Looking back over the mountains just now passed, we see them almost invariably dipping east and north-east, and their strike facing west or south-west. So we consider each range, sierra or cordillera, as the edge of a leaf in the great book of geogony. Few of them have been opened so as to allow some reading on one or the other page, whilst the greater number still remained closed, just with their edge turned up a little. It is our impression, that whenever time for further revelation shall arrive, these mysterious sheets will be turned from the west to east.

The sierras Madre, Santa Cruz, Pajarito, Santa Barbara, Santa Rita, and others of that region, have developed some parts of their geological history, whilst those western ranges have hardly commenced to do so. Earthquakes are not uncommon through the basin of the California Gulf; a mud volcano, on the eastern foot of the cordilleras of Lower California is still in activity; the lower Colorado, itself, is almost dry, and active to change not only its banks, but also its innumerable bends, of which, below the mouth of the Gila, exists only one retaining its original shape among all these changes. The navigators of this river call it, therefore, "the permanent bend."

In the face of these facts we cannot doubt that this country has not yet passed through all the phases of its existence.

We do not, however, believe that any great and violent general catastrophe will be necessary to bring the things to pass. A long continued, perhaps imperceptible rise of country, the simple increase of elevation, and especially the enlargement of the angle of inclination to which the level of these deserts may become subjected, might aid the torrents of the mountains and the sweeping winds to clear the surface of this land from its terrible burden, which is adverse to the purposes of man, and to the still higher ends of nature.

### 4. On the Carboniferous Limestones of the Mississippi Valley. By Professor James Hall, of Albany, N. Y.

*Abstract.*

The object of this communication was to show that certain reliable and well-marked subdivisions exist in the carboniferous limestone, as it is usually termed, of the Mississippi Valley. The subdivisions heretofore proposed, were in part founded upon certain supposed characteristic fossils, such as the Archimedes,* the Pentremites, etc., which, though reliable as individual species in their geological range, are not as genera characteristic of the subdivisions.

The subdivisions proposed in the report of Dr. D. D. Owen were, first, an upper and a lower series, each of which was again subdivided into several distinct beds or groups. For the sake of comparison, rather than for criticism, this table of formations of Dr. Owen is here given.

*Professor Owen's Table.*

| | |
|---|---|
| Bituminous shale | |
| Bed of coal six to eight inches thick | |
| Upper concretionary limestone | 20 ft. |
| Gritstones | 10 " |
| Lower concretionary limestone | 30 " |
| Gritstones | 10 " |
| Magnesian limestone | 10 " |
| Geodiferous beds | 30 " |
| Archimedes limestones | 50 " |
| Shell beds | 15 " |
| Keokuk cherty limestones | 15 " |
| Reddish brown Encrinital group of Hannibal | 70 " |
| Encrinital group of Burlington | 55 " |
| Argillo-calcareous group, Evans' Falls | 75 " |

The above represents an approximate thickness, as given by Professor Owen.

* See description of *Fenestella* (*Archimedes*) in a following paper.

Professor Swallow, in his report on the Geological Survey of Missouri, subdivides the Carboniferous limestones, and the rocks below the coal-measures, as follows: —

| | | | |
|---|---|---|---|
| Carboniferous limestones. | E. | Lower coal-measures | 140 ft. |
| | F. | Ferruginous sandstone | 195 " |
| | G. | St. Louis limestone | 250 " |
| | H. | Archimedes limestone | 200 " |
| | I. | Encrinital limestone | 500 " |
| Chemung group. | J. | Chouteau limestone | 70 ft. |
| | K. | Vermicular sandstone and shales | 75 " |
| | L. | Lithographic limestones | 60 " |

Under each one of these divisions are given numerous localities, where the rock is well developed.

In descending the Mississippi River, we come upon the lowest and most northerly outcrop of the limestones, at Burlington in Iowa.

At this locality we have the following section in the descending order: —

1. Encrinital limestone.
2. Oolitic limestone, fossiliferous.
3. Compact arenaceous limestone.
4. Fine grained argillaceous sandstone or gritstone with casts of Spirifer, Chonetes, Productus, Bellerophon, Orthoceras, etc.
5. Green shale.

The entire thickness of 2, 3, 4, and 5, is about sixty-five to seventy feet; the base of the green shale, however, has not been observed.

These members constitute the Argillo-calcareous group of Evans's Falls in Dr. Owen's section; and the members J. K. and L. of Professor Swallow's section. The higher beds of these strata belong to the Chemung group, containing the same fossils as the rocks of that group in New York and elsewhere, and have been carefully traced throughout the intermediate space. It is quite probable that in strict parallelism the green shale of Burlington and Evans's Falls, which weathers to an "ash-colored earthy marlite," should be referred to the Portage group, since here it lies between well-marked Hamilton beds and the Chemung. And it is likewise probable that the lithographic limestone of Professor Swallow will be found more closely allied with the Hamilton than with the Chemung group.

We have, however, in the light-colored friable sandstones of the

Chemung group, a well marked and reliable horizon. The Oolitic bed is more closely allied by its fossils with the Chemung below, than with the Encrinital limestones above; though between the latter there is often no well-marked physical line;—so gradual and imperceptible is the change from what is termed Devonian to the acknowledged Carboniferous rocks.

The Encrinital limestone of Burlington, or, as we shall hereafter term it, the *Burlington limestone*, is characterized by its great number of Crinoids, of which Drs. D. D. Owen and B. F. Shumard have described numerous species. The rock is in a great measure composed of the broken and comminuted remains of this family of fossils. Large masses of the rock consist almost entirely of the separated but unbroken joints of the columns of various species of Crinoids.

This rock includes the "Encrinital group of Burlington," and the "Reddish brown Encrinital group of Hannibal," in Missouri, of Dr. Owen's section; the latter being in no respect different from the former, and holds precisely the same position in the series, having the same beds above and below it.

The "Encrinital limestone" of the Missouri report is likewise identical with the Burlington limestone, and is so recognized by Professor Swallow.

The Burlington limestone is succeeded by Cherty layers, with intercalated beds of light gray limestone; these are the Keokuk Cherty limestones of Dr. Owen. They have a thickness, altogether, of sixty to one hundred feet, and constitute the beds of passage to the next division of the limestones. These cherty beds form the rapids above Keokuk, so well known in the navigation of the Mississippi River. These constitute, also, the so-called Silicious formation of Tennessee and Alabama.

The second important limestone is recognized, both in the section of Professor Swallow and Dr. D. D. Owen, as the "Archimedes limestone," from containing the Archimedes of Lesueur, a Bryozoum of the Fenestella family, with a spiral axis.

On descending the Mississippi River this limestone is found at Dallas, at Appanoose, and opposite to Madison, and at Nauvoo, Illinois, and is largely developed at Keokuk; the "shell beds" of Dr. Owen forming a subordinate member of the mass. The fossil Archimedes is extremely rare in all these localities, as well as at Quincy, Illinois,

where the lower part of the rock is seen resting on the cherty beds which separate it from the Burlington limestone.

This limestone, which may for convenience be termed the Lower Archimedes limestone, or Keokuk limestone, contains numerous characteristic fossils. In the upper part we find *Archimedes*, rarely, *Cyathophylli*, *Spirifer striatus*, fish teeth, etc. Among crinoids are *Platycrinus Saffordii*, *Actinocrinus Humboldtii*, *Agaricocrinus tuberosus*.

The Keokuck limestone is limited above by a mass of shales, or marls with impure limestones, known locally as the "Geode bed," from the numerous geodes lined with quartz, crystals, chalcedony, calc spar, etc., which it contains;—and which have been distributed very widely throughout the United States. This mass constitutes the "Geodiferous beds" of Dr. Owen's section; but has not been recognized in the Missouri section.

Succeeding the Geode bed, and occurring in the same localities near Warsaw, Illinois, at Appanoose, and other places, is a bed of Magnesian limestone, recognized in Dr. Owen's section under the same name.

To the Magnesian limestone, which has a thickness of some ten feet, and is doubtless only of local development, succeeds a series of beds of blue "marlites," with intercalations of impure limestones, or, in some places, impure limestones separated by seams of blue marl. The upper portions become arenaceous, and sometimes contain small pebbles, forming the "Gritstone" of Dr. Owen's section. The central and principal portion is highly fossiliferous, abounding in reticulated bryozoa; and among these the axis of a species of Archimedes occurs in great numbers and of extraordinary size and perfection. So abundant is it that a score of individuals may sometimes be seen in the space of a few feet. This species is quite different from the one in the Keokuk beds; being more robust and the volutions of the spiral lip rapidly ascending. This limestone, in some localities, contains Pentremites in considerable numbers.

This *second* Archimedes limestone seems not to have been recognized in the section of Dr. Owen; and judging from localities cited, it appears to have been confounded with the lower Archimedes, or Keokuk limestone. The position, however, of the Warsaw Archimedes limestone is above the Geode bed; the Archimedes is a distinct species, and it is associated with several species of crinoids, fish teeth, etc., which do not occur in the lower beds.

The arenaceous bed which terminates this group, and which like-

wise contains Archimedes and joints of crinoidal columns, is succeeded by a light gray compact limestone, which is often concretionary or brecciated in its structure. Its most conspicuous fossil, in many localities, is *Lithostrotion floriforme*.

This limestone is termed by Dr. Owen the "Concretionary limestone," and by Professor Swallow the "St. Louis limestone." * It is the same rock which forms the low cliff below Keokuk, near the mouth of the Desmoines River, and at St. Francisville, Missouri; the greater part of the bluffs on the river for some distance above Alton, Illinois; the limestone of St. Louis, in whole or in part; the limestone of St. Genevieve; the limestone of Prairie du Rocher, Illinois; and in part of the bluffs bordering the American bottom below Alton.

At this point the sections of both Dr. Owen and Professor Swallow cease, so far as limestones are designated. The concretionary limestone of Dr. Owen is succeeded by sandstones and shales of the coal-measures; which is the true order at the mouth of the Desmoines and other places, but not universally true. In the section of Professor Swallow, the St. Louis limestone (concretionary limestone of Owen) is shown to be succeeded by a brown or ferruginous sandstone, F. of section in Missouri report; and upon this rests the lower coal-measures.

This order is likewise true in some parts of Missouri and of Illinois; but it is not everywhere true in these States. The ferruginous sandstone is in turn succeeded by an extensive and important limestone formation, which consists of beds of limestone of greater or less thickness, alternating with thin seams of marl or shale, and in some parts heavy bedded limestone of considerable thickness without shaly partings, or with very thin ones. The group embraces, likewise, one or more heavy sandstone beds, and a mass of green shale or marl, more than fifty feet thick in some localities.

This formation constitutes the limestones of Kaskaskia and Chester, Illinois; and those below St. Genevieve in Missouri. They likewise occur at other places on the river, and form the greater part of the limestones of Southern Illinois, and Indiana, and those of Kentucky

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* After a careful examination of the locality cited by Dr. Owen, I am unable to find a "*second* concretionary limestone;" though it is not difficult to see how such an error may have occurred in measuring the section near the mouth of the Desmoines River.

This limestone is likewise known as the Archimedes limestone, and sometimes as the Pentremital limestone from the abundance of Pentremites it contains. The species are distinct from those of the Pentremites of the Warsaw Archimedes limestone. This rock has evidently been always confounded with the lower Archimedes or Keokuk limestone, as is shown by localities cited in the reports above-mentioned, and in other publications upon Western geology.

The species of Archimedes, which it contains in great numbers, are quite distinct from the other two named; and the character of the axis of these fossils alone, is quite sufficient to distinguish the rock from either of the lower ones. The stratigraphical position of this rock is most clearly defined and readily determinable. The assemblage of fossils is quite distinct from all those in the rocks below, and there remains no reason for confounding it with either of the other divisions.

In following down the course of the Mississippi River, the St. Louis limestone is seen to pass beneath the ferruginous sandstone F.; and upon the latter rests the limestone group of Kaskaskia in Illinois, and of St. Mary's in Missouri.

From these data we are prepared to show the true order of the successive members of the carboniferous limestones of the Mississippi valley in the States of Iowa, Illinois, and Missouri, and also in Indiana, Kentucky, Tennessee, and Alabama.

The following section illustrates the preceding statements regarding the order of superposition among the different members of the limestone series.

| | | |
|---|---|---|
| VII. | Coal-measures. | |
| VI. | Kaskaskia limestone, or Upper Archimedes limestone. | Kaskaskia and Chester, Ill.; St. Marys, Mo. |
| V. | Gray, brown, or Ferruginous sandstone overlying the limestones of Alton and St. Louis. | Below St. Genevieve, Mo.; between Prairie du Rocher and Kaskaskia, Ill. |
| IV. | "St. Louis limestone." Concretionary limestone" of Dr. D. D. Owen. | Highest beds below Keokuk, Alton, St. Louis, St. Genevieve. |
| III. | "Arenaceous bed." Warsaw or Second Archimedes limestone. "Magnesian limestone." | Warsaw and above Alton, Ill.; Bloomington, Spergen Hill, etc., Iowa. |
| Beds of Passage. | Soft, shaley, or marly beds with geodes of quartz chalcedony. | |

| | | |
|---|---|---|
| II. | Keokuk, or lower Archimedes limestone. | Keokuk, Quincy, etc. |
| Beds of Passage. | "Cherty beds," sixty to one hundred feet. | Rapids above Keokuk. |
| I. | Burlington limestone. | Burlington, Iowa; Quincy, Ill.; Hannibal, etc., Mo. |
| | Oolitic limestone and Argillaceous sandstone of the Chemung group of New York. | Burlington, Iowa; Hannibal, Mo.; and other localities. |

The difficulties which have occurred in the way of a reconciliation of the views of western geologists, have arisen in part from the fact that these different limestones have not an equal geographical distribution; there being no point on the Mississippi, within our knowledge, where a section at right angles to this valley will embrace all the beds here enumerated. The limestones, likewise, change their character when examined in a north and south direction, owing to causes which will be enumerated. The fossil forms which have mainly been relied on for characterizing the divisions, have been, to considerable extent, only of generic value, and specific differences have not always been properly recognized.

In the geographical distribution and the changes of lithological character, at different points, we have yet much to learn. These successive formations of limestone have been deposited in an ocean which was gradually contracting its limits upon the north. The lowest, or Burlington limestone, has, therefore, a greater extension northward than either of the succeeding groups, and its gradually thinning edges stretch far towards Iowa City; near which latitude was the northern boundary of the ocean, or at least the limit of its animal life. Considerably to the southward of this line we first find the attenuated northern edges of the Keokuk limestone, mingled with much earthy sediment, and often consisting of a few thin beds of encrinital limestone intercalated among other beds of an argillaceous character. It is only further south, in the neighborhood of Nauvoo and Keokuk, that this limestone first exhibits decidedly its characteristic features. The limits of the ocean which admitted of rock deposition at this period, never extended so far north, by many miles, as in the period of the Burlington limestones.

The Warsaw Archimedes limestone appears to have been nearly

co-extensive with that below, so far as known at present. The St. Louis limestone extends northward, also, nearly or quite to the same distance, but only in a thin, brecciated, or conglomeratic mass; and it is only on descending the valley to the vicinity of Alton, that this rock appears in any considerable force.

To these beds succeed the sedimentary deposit of Ferruginous sandstone, which, in the river valley, is not known far to the north of St. Louis; while the succeeding Kaskaskia limestone becomes important in the neighborhood of the Kaskaskia River; and is known in the interior as far north as Prairie de Long, increasing in force as we go southward.

We have most clearly, therefore, the evidence, that the limits of the ocean, admitting of calcareous deposition, was gradually contracting, at least in the direction from north to south, leaving the more southerly portions as the areas of greatest development for these limestones, which, in the successive periods, were gradually extended farther and farther to the southward.

Some interesting inquiries are suggested by these facts; and at the same time they afford, in some degree, the solution of a difficulty which has heretofore been unexplained.

It is well known that no limestone of the age of those here described, occurs beneath the coal-measures on the western side of the Appalachian coal-field, north of the Ohio River, nor upon the eastern side of the same field, until we reach the central portion of Virginia. The same is true of the coal-fields of Nova Scotia and New Brunswick, according to Professor Dawson; the northern sides exhibiting no underlying limestones; while these rocks do appear, coming out from beneath the coal-measures, on the south-eastern side. The same phenomena occur in regard to the northern portions of the Illinois and Iowa coal-fields.

At the same time, I have ascertained in the most satisfactory manner, that the coal-measures of Iowa, Missouri, and Illinois, rest unconformably upon the strata beneath. Whether these strata be the carboniferous limestones already referred to, the Devonian, the upper silurian, or lower Silurian rocks; in either case the measures are unconformable, differing only in degree.

It would appear that at a period long preceding the commencement of the carboniferous limestone deposit, the ancient ocean began to contract its area; that this contraction was due to the uplifting of the

older rocks upon the north; and that this state of things continued throughout all the period of the limestone deposites. That during this period, or at its close, and previous to the deposition of the coal-measures, the older strata becoming uplifted, and at some points broken by faults, in many places acquired a dip of from ten to thirty degrees; that denudation had worn down, to some extent, the inequalities caused by this uplifting of the strata, and produced other irregularities of the surface.

The coal-measures extend much farther to the north than the northern limits of the carboniferous limestones, and are spread out over the thinning and slightly inclined edges of these beds, and over the more disturbed and more highly elevated edges of the rocks of the preceding periods. Thus the coal-measures rest respectively upon all the formations, from *lower Silurian* to the *carboniferous limestones*. The only explanation we can offer is, that the area of the ocean, which had contracted up to the time of the coal period, was afterwards extended by the sinking of the land; allowing the sandstones and shales of the coal-measures, as well as subordinate beds of limestone, to be spread over much wider areas than the preceding formations of carboniferous limestone. This accounts for the absence of the carboniferous limestone, in the northern portions of all the coal-fields.

It is true, however, that the carboniferous limestones of Nova Scotia have a more northerly extension than the northern limits of the Appalachian coal-field; but if these limestones of Nova Scotia be of the same age as those of the south-west, their occurrence may be due to the direction of the ancient ocean margin, or the line of ancient coral reefs. It appears that this direction may have been from the south-west to the north-east, at least for that portion of the country east of the Cincinnati axis; while on the west of that line, the lower carboniferous limestones make a northerly bend, as if at that period the valley of the Mississippi admitted of a more northerly extension of the coral reefs.

This view, sustained by facts, while it offers a general solution of the difficulty respecting the non-occurrence of carboniferous limestones on the northern sides of all the coal-measures, at the same time suggests an explanation of the greater accumulation of conglomerates and coarser materials in the same position.

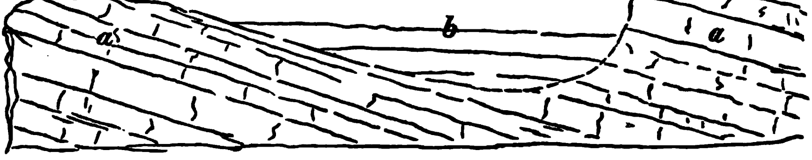
The high elevation of the older strata, and the inequalities of surface on which the western coal-measures rest, prove conclusively that ex-

tensive denudation had taken place previous to the coal period; and this fact, connected with others of similar character, should suggest a caution in our conclusions regarding the vast influence of modern denudation upon the surface of the globe.

Among the remarkable and interesting consequences of this ancient denudation, it is not unusual to find depressions among the inclined strata of the silurian rocks, filled with regular coal deposits, lying usually in a horizontal position, or with a slight dip, varying from that of the surrounding rock. These outcrops, which sometimes occur in ravines, have all the aspect of regular coal-measures, which, from the direction of the bed, would penetrate the bank, but which are, nevertheless, cut off by the inclined strata, within a few yards. Isolated masses of this kind are not uncommon, both in Iowa, Illinois, and Missouri, lying at the foot of elevations, and apparently penetrating the adjoining elevated ground. In the latter State, these, in many instances have been worked entirely out, and proved to have no connection whatever with the adjacent beds, or with any other coal in the vicinity.

In several localities on the Mississippi River, in Iowa, the older rocks, dipping to the northward at an angle of perhaps ten degrees, present the outcropping edges at points more or less distant from each other, while the intermediate space is occupied by strata of the coal-measures, lying in a horizontal position. These phenomena have been mistaken for faults; but they are far different in their origin, and the coal-measures have apparently never been disturbed from the time of their deposition.

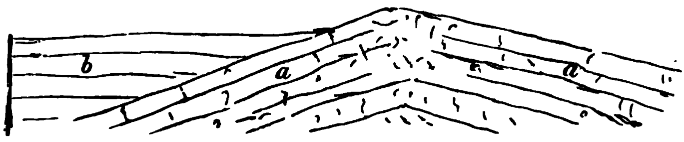
Among the examples of this kind may be noticed more than one between Davenport and Le Claire. Within three miles of the latter place, the strata of upper Silurian limestones are dipping to the northward, and between two points of outcrop, horizontal beds of coal shale, sandstones, and iron ore, occupy the spaces, thus:—




*a a.* Outcrops of Silurian limestone, as seen above the level of the river, dipping at an angle of 15°.

*b.* Coal, shales, and sandstones lying in horizontal position.

In another instance, the coal-measures present the following relation to the underlying rocks: —




*a a.* Axis of Silurian limestone.
*b.* Horizontal coal-measure strata, traced to within three feet of actual contact with the limestones, which dip at an angle of 30°.

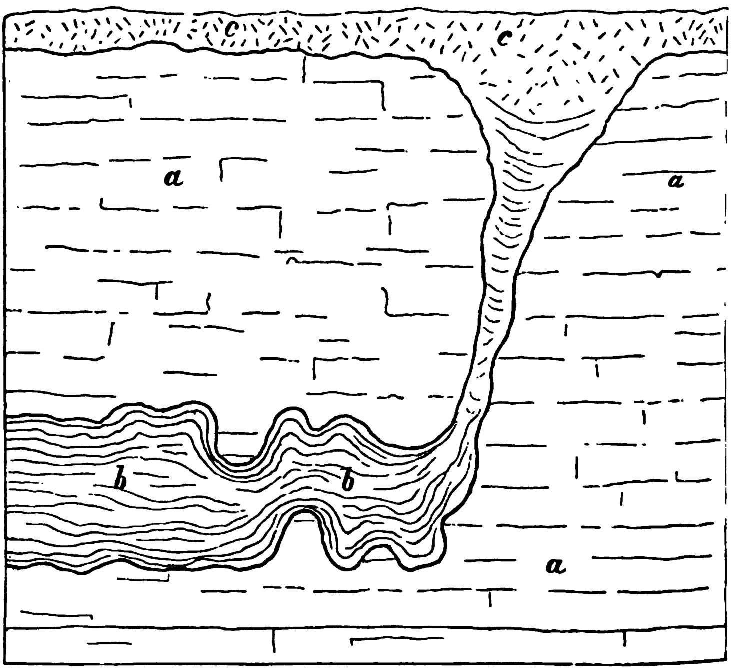
A still more interesting exhibition of phenomena attendant upon this condition of the strata is the occurrence, in limestones of the age of the Hamilton and Upper Helderberg groups, of rounded or irregular masses of clay, like the underclay of coal seams. These masses, which are seen in sections along the river, and in quarries, often present simply the appearance of a spheroidal mass of clay. Sometimes the larger mass is traced through a narrow seam to a connection with another similar one in a higher bed of the rock; and it not unfrequently happens that these clay seams, which are always vertical to the bedding of the limestone, may be traced to the surface, and the clay found mingled with the superincumbent materials as if having a common origin. On examining the surfaces of contact between the clay and limestone, we find the former adhering closely, and when separated, the limestone still retains a striated coating of the clay. The clay is laminated, and the laminations are curved or irregular, but never parallel to the lines of bedding in the limestone.

A single instance of this character satisfied me that these masses of clay were of subsequent deposition to the limestone; and that they filled cavities which had been made by denudation, like modern caverns in limestone.

This example was in the vertical face of a quarry, presenting an elevation of thirty or forty feet. From the loose soil above, was a depression at the surface of the limestone; this depression was the commencement of a broad, funnel-shaped opening, which gradually narrowed below, till within ten feet of the bottom, where it spread out on one side, having an irregular arched roof with numerous smaller archings, and an unequal floor. Its termination to the left had in part been cut off. This cavity from top to bottom was filled with hard clay, like the

underclay of coal seams. At the mouth of the funnel it was of a reddish brown hue, but soon became of the ordinary gray color below.* The laminations of this clay, in the upper part, conformed to the curvatures and inequalities of the roof of the ancient cavern, and exhibited every appearance of having flowed in while in a semi-fluid condition; while the hydrostatic pressure of the mass above, operating through the deep funnel, had forced the soft clay against the roof, causing it to assume, in its lamination, the same curvatures and irregularities.

In the midst of this mass of clay was the impression of a large *Euomphalus;* quite distinct from any fossil known in the surrounding rock, and very similar to a carboniferous form. The shell itself I did not see; and with this exception, I found no traces of fossils in the clay.




*aaa.* Limestone of Devonian age.
*bbb.* Ash-colored clay, similar to the underclay of a coal seam.
*cc.* Gravel and yellowish loam.

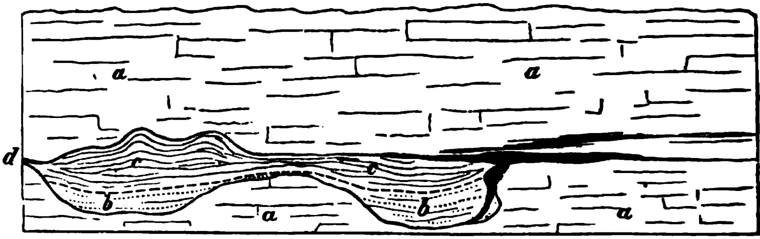
* The reddish brown color is simply due to infiltration from the ferruginous drift above.

It seems impossible, therefore, to resist the conclusion, that after the uplifting of these rocks, the denudation of the surface, and the wearing of caverns below, the materials of the coal-measures were distributed over the surface, filling these cavities, and depositing the successive members of the coal series upon the older rocks.

If any thing were wanting to complete the chain of evidence and carry the most conclusive proof, it is to be found in a section near Iowa City. In a cliff of limestone of the age of the Upper Helderberg of New York, where the strata are nearly horizontal, we have the following phenomena. Along the line of separation between two beds of limestone, appears a black band extending for thirty or forty feet; beneath this, occupying less horizontal extent, and partially filling a depression excavated in the limestone beds below, is a thicker layer of clay, precisely like that filling the cavities before described, and of the character of underclay; and still below this, occupying the depth of the cavity, is a coarse sandstone. This sandstone, in its lines of lamination or bedding, follows the curvatures of the limestone upon which it lies, gradually filling up the cavity from below, and extending its laminæ above as the space becomes wider. Upon this comes the underclay, filling the upper and broader part of the cavity, and having a greater horizontal extent than the sandstone below. Above this underclay, and stretching for several yards on either side, filling the open seam between the beds of limestone, is a band of black carbonaceous mud, the lower part slaty, and the upper part having the character of *cannel coal.* Here we have all the phenomena attending a coal-measure seam of coal; the sandstone, the underclay, and the seam of coal resting upon the latter: and as if nothing were wanting to complete the similarity, the slaty portion of the seam contains *fish teeth* of carboniferous character. All this is inclosed in limestones, which, in the State of New York, where the series is more complete, lie at a depth of more than 5,000 feet below the coal-measures.

In this instance the explanation is clear enough. It is only a little more complete in its members than the preceding example, while the aperture of admission from above is not visible. The coarse and fine sand were first transported; and falling through an opening in the rock, continued in deposition in this cavity, while a bed of similar sandstone was being formed outside, and upon the bed of the sea. This ceased, and then came the underclay, which was formed in like manner while

the underclay deposit of extensive coal beds was going on. Lastly appeared the carbonaceous mud, derived from a coal seam, or from the materials forming one of the seams of the coal-measures.




*a a a a*. Limestone of Devonian age.
*b b*. Coarse sandstone in curved laminæ.
*c c*. Ash-colored and greenish ash-colored underclay.
*d d*. Coal seam with shaly mud containing fish teeth.

There is here no mingling of materials, as if resulting from the breaking up of a coal seam at a later or modern period, and the filtration through a seam into the rock; on the contrary, every part is as distinct as in the coal-measures elsewhere, and it could only have resulted from a participation in the causes then operating to produce those extensive beds of sand, clay, shale, and coal, which make up the coal-measures.

It should not be forgotten, moreover, that this point is near the northern margin of the coal-fields, and beyond the limits of any productive coal seam; a few isolated patches of sandstone and shale being all the remaining evidences of the existence of the series in that vicinity.

This cavernous condition of the limestone is not confined to the immediate vicinity here described, but extends over large areas in Illinois and Iowa. The fissures are sometimes partially filled, and sometimes open.

In Wisconsin, Illinois, Iowa, and Missouri, the fissures or caves occupied by the lead ore are apparently of similar character and origin; the period of their production being a point for discussion. Whatever may be said to the contrary, it appears still very certain that these lead-bearing fissures have no connection with the rock below; and also, that the character of the fissures, with the material filling them, indicates an action from above. That these cavities were excavated, and

subsequently filled or partially filled with the ores of lead, zinc, or iron, by infiltration from above, as stated elsewhere by the writer,* seems as well settled a problem as that the coal seam just noticed is due to infiltration from above.

The age of the rock in which the lead occurs is not a question affecting the origin of the mineral matter; for while in Iowa, Wisconsin, and Illinois, the lead rock is an upper member of the Trenton limestone period, it is in Missouri the calciferous sandstone, a rock far older than the Trenton period. The mode of occurrence of the ore is similar in both places.

The fact that the calciferous sandstone in Missouri is the lead-bearing rock, and that sometimes in Upper Iowa and Wisconsin the same rock contains some lead ore, has induced the belief that the origin of the ore is from below. It is true that the calciferous sandstone is spread over large areas of country on the north of the productive lead region of Illinois, Iowa, and Wisconsin, but thus far it has yielded no valuable lodes. It is likewise less cavernous than the lead-bearing or Galena limestone, and far less so than the same rock in Missouri.

From what we know, it appears that neither the carboniferous limestones nor the coal-measures ever extended so far north as the northern lead-bearing rock, while these strata do occupy the country around the lead region of Missouri, and outliers of coal-measures often rest directly on the calciferous sandstone, the lead-bearing rock of that State.

There is, therefore, a strong evidence in favor of regarding these fissures and caverns, whether filled or otherwise, as having been formed during the Carboniferous period, and previous to the deposition of the coal.†

* The same views in reference to the origin of the lead ores are entertained and have been published by Mr. J. D. Whitney.

† In making this statement the writer would not be understood to say that similar fissures and caverns may not have been produced in these rocks during the modern period, through the drift or other degrading agencies, which, at the same time, may have removed the clay or other mineral matter from caverns of previous date, rendering the determination of the period of their origin a matter of considerable difficulty. At the same time the existence of the fissures filled with mineral matter, accompanied or unaccompanied by a peculiar clay quite different from the drift materials of the region, or filled with this clay alone, or with indurated clay like the underclay of coal seams, either with or without the presence of sandstone and coal all point to a period long anterior to that of the modern drift.

The elevating forces which have raised the precarboniferous strata to their present inclination throughout the West, have had a determinate direction; and this direction has been from north-west to south-east, parallel to the great mountain ranges on the west, and nearly at a right angle with the Appalachian chain on the east. So far as my opportunities permitted the determination, the general direction is north 40° or more west.

In descending the Mississippi, we first notice that the strata rise and fall in broad undulations, which cross the direction of the valley from north-west to south-east. Still lower down we meet with more abrupt anticlinal axes; and in one of these, at the Upper Rapids and below, are several minor plications. Below Davenport there is considerable regularity; and between this point and Cap au Gris are again broad undulations, which reveal, successively, all the strata from the carboniferous limestone to the lower Silurian rocks. In approaching Cap au Gris from the north there is a gradual rising of the lower strata, so that the Trenton limestone is beautifully defined for some distance; and beneath it lies a magnesian limestone apparently of no great thickness. The dip to the north-east increases, and from beneath these limestones the sandstone rises in a bold escarpment continuing for three fourths of a mile, and presenting several hundred feet of thickness. This elevation suddenly declines to the southward; and we find the Burlington or lower carboniferous limestone standing vertically by the side of the lower sandstone. The limestone soon assumes a steep, and gradually a more gentle dip to the south, and the succeeding members come in successively. This fault, which is in fact an anticlinal axis, has a north-west and south-east direction, and, according to the observations of Mr. Worthen, extends far into Illinois.

Below St. Louis, in the vicinity of Selma, there is another decided anticlinal axis, bringing up the lower sandstone. According to the Missouri report, the lower limestones and sandstones are again brought up in the vicinity of Bailey's Landing, but I have personally examined the strata at this place only so far as to decide that the upper Silurian strata appear from beneath the upper Helderberg and Hamilton groups; beyond which the carboniferous limestones appear to come in unconformably in the synclinal axis.

Still another axis of very decided character brings up the Trenton limestone in great force at Cape Girardeau, on the Missouri side, and at

Orchard Creek, below Thebes, on the Illinois side of the river. This axis affects all the southern portion of Illinois, below a line drawn from Fountain Bluff, on the Mississippi, to near Golconda on the Ohio. In some parts of its course this axis would appear to have a direction of nearly north 35° west, and south 35° east. In a country, however, where denudation has taken place to such an extent, and succeeding strata are spread over the uplifted edges of those below, it is often difficult to determine the exact direction, until traced over a wide extent.

That these lower axes crossing the Mississippi are the results of the great movement which elevated the fundamental strata of the western mountain chain, we can have little doubt. The forces that there acted upon the huge pile of sedimentary strata, raising them into high mountain chains, here operated upon a thickness of a few hundred feet; and we may have, not only the dying out of the elevating force, but also the diminished thickness of the strata for the subject of its action. If the force which elevated the Rocky Mountain chain acted only on the palaeozoic strata, the greater amount of material in that direction would give greater elevation to the ridges, which under similar force would die out in the Mississippi valley for want of material to be elevated.

The discussion of this part of the subject, however, does not properly enter into the present paper, and will be postponed to another accasion.*

A few words may suffice to express for the present the general features of the series of these limestones on the south of the Ohio River. All the members, with the exception of the higher or Kaskaskia limestone, gradually thin out to the south. The "*Siliceous Group*," as it is termed in the Geological Report of Tennessee, lies at the base

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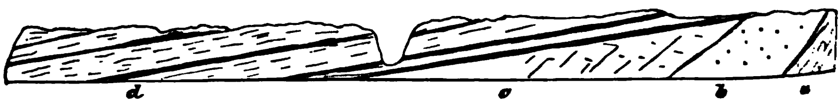
* See Introduction to Vol. III. Paleontology of New York. I may remark in this place that the observations made, and the collections brought home by Captain Stansbury, from the Salt Lake region, demonstrate that the upper carboniferous limestone, in an unaltered or scarcely changed condition, and bearing numerous fossils, rests unconformably upon metamorphic rocks of older date corresponding with what is so well shown in the Mississippi valley.

The topography accompanying these observations, also shows that these mountains of limestone have a nearly north and south direction; corresponding, doubtless, with the direction of the fundamental axes of the country.

of the carboniferous limestone in that State. This siliceous group is simply an extension of the cherty beds lying between the Burlington and Keokuk limestones, represented in the section between I. and II., which become largely developed in the south. The Burlington limestone is rarely seen, occupying a few feet of thickness beneath the "Siliceous Group." The Keokuk, Warsaw, and St. Louis limestones have thinned out so far as to form no important feature in the series, while the Kaskaskia limestone predominates over the whole country; and is there the great carboniferous limestone, yielding its abundance of Pentremites and Crinoids throughout its extent in Tennessee and Alabama.

NOTE. — So far as I know, the first notice of the unconformity of the Western coal-measures with the older rocks, was brought out, at the Providence meeting of the American Association for the Advancement of Science, in a discussion upon a section of the coal-measures of Northern Illinois, presented by Edward Daniels, Esq. This gentleman afterwards visited and reëxamined the locality, and communicated to me the following section as confirmatory of the views I had there expressed. The communication bears date of November, 1855.




*a*. Calciferous sandstone.
*b*. St. Peters sandstone.
*c*. Trenton and Galena limestone.
*d*. Coal-measures resting unconformably upon the rocks below.

In a Report upon the Mineral Resources of the Illinois Central Railroad, by J. W. Foster, published in 1856, a section similar to the one above is given; and the credit of the discovery of the relative position of the two series of rocks is there attributed to Dr. Norwood, the geologist of Illinois. It is certainly probable that Dr. Norwood has been aware of this fact for a long time, and the writer, in common with many of his friends, has had occasion to regret that Dr. Norwood has not long since published some portion of the accumulated facts of many years of investigation.

Although aware, for several years, of this relative position of the lower rocks and the coal-measures, yet I was never so fully impressed with the high interest and importance of the matter, until I had carefully followed out the successive members of the carboniferous limestone series. Disclaiming any desire to appropriate the discoveries of others, the writer has presented, in the preceding paper, the facts that came under his own observation, and the conclusions which seemed legitimately deducible therefrom.

I should do injustice to my own feelings were I not in this place to acknowledge the valuable aid rendered to me by Mr. A. H. Worthen, my assistant in the Geological Survey of Iowa, whose intimate acquaintance with the principal localities of the carboniferous limestones in the Mississippi valley, enabled me to accomplish my investigations in much less time and with far more satisfaction than I should otherwise have been able to do in a single season. We explored together these formations as far as the mouth of the Ohio, after which Mr. Worthen carried on, under my direction, the observations through Tennessee and Alabama, with a view to the recognition of the groups established in the investigations in Iowa, Illinois, and Missouri.

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## 5. Remarks on Niagara Falls. By Professor L. R. Gibbes, of Charleston, S. C. (In the form of a letter addressed to James Hall, President of the Association.)*

A pamphlet of Desor's † has lately fallen into my hands, in which he opposes your view of the condition of the Falls of Niagara, after a supposed recession of one and two miles, and, arguing from the rate of recession of the American Fall, since the time of Hennepin, expresses the opinion that the falls, instead of receding at the rate of a yard per annum, do not recede a foot per annum, and in fact that the rate is a *mere fraction of a foot.*

Now I cannot assent to his applying to the Canada Fall the result drawn from the American Fall, since he omits to take into consideration the very different rate of recession of the two falls. If we assume, what is generally granted, that the gorge or chasm, from the bluffs at Lewiston to the Canada Fall, has been excavated by the action of the falls themselves, then there must have been a period, anterior

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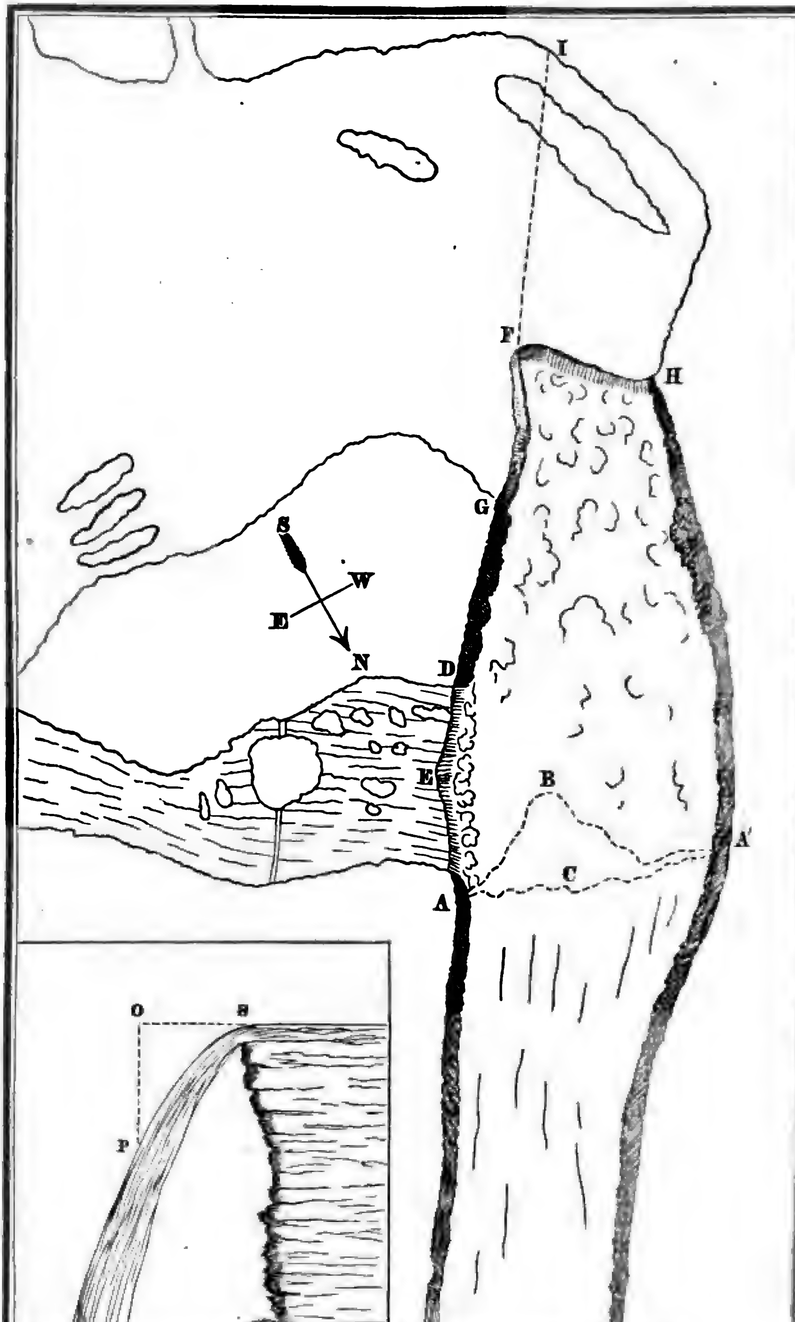
* This paper was communicated to the President of the Association, at the Albany meeting, with a request that he would lay it before the Association, with his comments. For want of time and ability on his part, it was not brought before the meeting, but was presented to the Standing Committee, who directed that it should appear in the proceedings. — J. H.

† Extracted from Bulletin de la Soc. des Sci. Naturelles de Neufchatel. Tome III.



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to the division of the falls into two as at present, when there was but a single fall extending from A to A′, just below the American Fall, whose brink was along some irregularly curved line as A B A′ resembling that of the Canada Fall at present, or along some irregular line A C A′ approximating to the straight line joining A A′, resembling in this particular the American Fall. Then, if we assume that the river or portion of the main stream now forming the American Fall did at that time communicate with the main stream by the outlet A D, it will follow that while the centre of the American Fall receded from B or C to E, the centre of the Canada Fall receded *in the same interval* from B or C to F. From C to F is at least three times the distance from C to E, and from B to F is about four times the distance from B to E, so that *the recession of the Canada Fall is, on this supposition, at least from three to four times as rapid as that of the American Fall.*

This point is overlooked, or at least omitted, by Desor, so that his result drawn from the American cannot be applied without modification to the Canada Fall. I do not find that you have anywhere taken notice of this inequality of recession, or alluded to the causes which have produced it, nor can I find that other writers on the topography, geology, or phenomena of the falls, as Eaton, Hayes, or Rogers, make mention of it.

Putting aside the consideration of any actual inequality in time of action, that is, regarding it as impossible or exceedingly improbable that there should have been any natural dam or continuous obstacle from A to D, which gave way, some time after the main fall had passed the point D, permitting the American cascade then to begin its fall, there will remain two causes for the unequal recession of the two falls. These are difference in the volume of water, and unequal facility of abrasion possessed by the strata of rock in the two directions, C F and A′ A. Now, do either or both of these causes exist? if they exist, are they sufficient to account for the effect, the inequality of recession? It is twenty years since I visited the falls, but from my own recollections, as well as from the representations of visitors and the impression given by views of the falls, there can be no doubt that the volume of the Canadian Fall is much greater than that of the American Fall, and not only in length of the circuit of the brink, but in depth of water also, and possibly also in the velocity. With regard to unequal facility of abrasion in the two directions I know nothing but what the falls

themselves may show, for, as I have said, the geological observers do not appear to have mentioned it. That there is an unequal facility of abrasion in different directions appears to be indicated by the present condition of the falls. It is a very remarkable circumstance, and one whose value in the discussion of the past and future condition of the falls does not appear to be noticed or insisted upon, that the point A, the northern extremity of the American Fall, the point F, the vertex of the Canada Fall, and the two angles of Goat Island, D and G, are nearly in a right line, parallel to the general course of the gorge below, and at right angles to the general direction A A′ of the brink of the fall. It would appear, therefore, that the fall which had excavated the gorge below A A′, in a certain direction, had continued this excavation in the same direction, *uninfluenced by the presence and action of the American Fall*, except by the abstraction of that body of water, and had now assumed the position F H. With respect to its future condition, the Canadian Fall may be regarded as consisting of two portions, the one, F H, corresponding, in its relations to the strata beneath, to the original fall A A′, and the other, F G, in like relations, corresponding to the American Fall. If this view be correct, the general course of the Canadian Fall will be towards the point I, and the formation finally of a fall along the line G I, whose recession will be slower than formerly.

During the interval of time that the main fall was receding from A A′ to F H, a distance of about 1,000 yards, the American Fall must have receded from some line A D left by the abrading action of the main fall to its present position. The amount of this recession Desor estimates at forty yards, and this gives a rate of recession twenty-five times greater in one direction than in the other. This result must be reduced on account of the *gradual* development of the American Fall, while the main fall was receding from A to D. The result of this gradual development, will be the same as from the display of the whole force of the fall for half that time, and as A D is about one third of A F, if we suppose a nearly uniform rate of recession of the main fall, the reduction will be one sixth of the whole, leaving the ratio of recession as 1 to 20 or 21. This effect can scarcely be due to the difference of volume of water solely. The volume of water passing over any linear yard of the brink of either fall depends on the velocity and depth, and I have no means of ascertaining either of

these factors. It has been reported that the hull of a vessel, sixteen feet from deck to keel, was sent over the Canada Fall, that the deck was level with the water, and that the keel met with no obstruction in its passage; it was hence inferred that the depth of water at the brink of the fall was at least twenty feet. If we give the half of this depth to the American Fall, which I think is not too great, the above result would require a depth of 200 feet of water at the Canada Fall, greater than the whole height of that fall, 156 feet. I have been behind the Canadian Fall, and proceeded some distance along the ledge of rock, but can form no reliable estimate of the height of the under surface of the sheet of water. It can scarcely be less than fifty-six feet, leaving 100 feet as the utmost possible depth of the water at the brink of the fall; this would give but five feet for the depth of the American Fall, which surely is too little. I know of no observations to show that the velocity at the one fall is much greater than at the other, so that there remains only the unequal resistance in different directions of the strata collectively, to account for the remaining part of the effect, and this appears to be *required* to explain it, thus supporting what was already inferred from the rectilineal position of the four points, A, D, G, and F, that the rocks do resist unequally in two transverse directions. If we assume as above ten feet for depth of water at the American Fall, and a depth four times as great for that of the Canadian Fall, which does not seem extravagant, also a velocity at the latter fall twice as great as at the former, it would then require a resistance two and a half times greater in one direction than the other. Is this too great to be supposed? A still greater relative resistance to abrasion would be required if, instead of comparing the fall F H with the American Fall, we compare it with the other partial fall F G, unless we suppose in this last, a depth of water and velocity of flow, much less than in F H, which does not appear probable.

If the curved form of the Canadian Fall be regarded not as arising from the unequal resistance of the rock in different directions, but as the normal form throughout the course from A to G, it will still be true that the main fall has cut its path of nearly uniform width and direction, very nearly as though the American Fall did not exist, the vertex receding from B to F. The ratio of recess would then be as 40 yards to about 800 yards, or as 1 to 20, and reduced one fourth according to principles given above, would be as 1 to 15, which would

still require a resistance in the line of direction of the American Fall nearly twice as great as in the other, showing that the resistance was greater in one direction than in another, *at the American Fall*, if no where else.

Another mode of explaining the inequality of recession occurs to me; to suppose the effect produced by the volume of water is not proportioned to the volume simply, but to some power of the volume, as the $\frac{3}{2}$ power or the second power; but still the continuity of the line A D G to F, appears to me to require the supposition of a great inequality of resistance in transverse directions, since we cannot suppose any great inequality of depth or velocity in the two partial falls, F G and F H.

Good observations are wanting on the width, depth, and velocity of the streams at several points above the two falls, in order to estimate the volume of water passing over each, also of the velocity at or near the brink of each fall; then from the known volume, linear length of brink, known from survey, and the known velocity at the brink, the depth of water there might be computed for each, if required. The ratio of volumes of water compared with the ratio of recession would show how far inequality of resistance entered as a factor in the final effect.

Besides the usual modes of estimating the velocity of the stream, such as the space passed through in a given time by objects floating in the stream, etc., the following method might be practised, by observations on the parabola described by the cascades at different points. Direct the centre of the cross wires of a theodolite to the summit S of the curve of the cascade at a distance from the instrument known by survey, then turn the telescope through a known *horizontal* angle to the point O, then depress the telescope through a known *vertical* angle to a point P in the stream of water proceeding from S, then from these known angles, and the known depression of the points O and S below the centre of the instrument, and the distance of S, find the lengths of O S and O P in feet; then will the required velocity $v$ at the point S, be given by the equation $v = \frac{4 \times OS}{\sqrt{OP}}$. The chief difficulty will be in determining the point S or vertex of the parabolic curve.

The points I have sought to establish in the preceding paper, on the supposition that the gorge is excavated by the action of the falls themselves, are the following:—

1. That, from the sameness of direction of the sides of the gorge above and below the American Fall, the main fall has cut its way to G independently of the existence of a lateral stream or fall.

2. That the recession of the main fall is not less than ten or fifteen times greater than that of the American Fall, and, therefore, that no deduction from the recession of the latter is applicable to the former, without modification.

3. That, if the volume of water at the Canadian Fall be not so much as ten or fifteen times greater than at the American Fall, (which is unknown, but does not seem to me probable,) the resistance to abrasion offered by the strata, in the direction of the gorge, must be less than in the transverse direction at the American Fall, perhaps not half as great.

4. That in consequence of the continuity of the line A D G to F, it is probable that the abrasion in the Canada Fall takes place chiefly along the line F H, and that the recession of this fall will be in the direction of the line F I, so that finally the line of brink of the two falls, Canadian and American, will be nearly the same, along the line A I, or one parallel to it.

Postscript. — Through the kindness of Professor Hall I have seen a copy of his note to be appended to my letter to him on the Falls of Niagara. Only a few additional remarks on my part seem to be required.

The use of the term *abrasion* may not have been judicious; I desired to express, not the wear of the rock by attrition or erosion, by the mere friction of the water, but the whole wear, waste, or removal of the rocky strata by the mechanical action of the water in motion, in whatever way it occurred; I do not find that geologists use any definite term to express the sum or result of these actions, nor does a more appropriate one present itself to me at this moment than the word *abruption*, to express it.

Before venturing to offer suggestions with relation to phenomena that I have not recently examined in person, I of course prepared myself by studying the accounts given by others, as is implied in my letter, and certainly did not omit to read carefully Professor Hall's account of the falls, and of the geological structure of the precipice, in the Report of the Fourth Geological District of New York, and indeed his map

and sections of the falls were constantly before me while writing; the dip and strike of the strata were known to me, as also the position of the latter, with relation to the line of brink of the different falls. It was, therefore, not unknown to me that the general direction of the gorge was transverse, or nearly so, to the line of strike, but I did not allude to this point, because the fact of unequal resistance to *abruption* in different directions was first to be proved, and because if proved, I did not see, nor do I now see, how it might depend upon the position of the line of strike.

By the phrase "unequal resistance to abrasion or abruption," I do not mean *unequal hardness or difference of texture or of structure* of the rock in different directions, but by it I intended to express the bare fact that the abruption of the rock proceeded faster in one direction than in another, after making due allowance for the difference in the volume of water, leaving the cause or reason of this more rapid progress, for further investigation.

I by no means hold myself pledged to support the hypothesis of "unequal resistance," because I have once offered it. If the view of Professor Hall be correct, that the dip of the strata southward gives an increase of depth and of volume of water, as the falls recede, sufficient to account for the more rapid progress in the direction F I, then the whole effect will be referred to the most obvious causes, the volume and velocity of the stream, and the hypothesis of unequal resistance will be unnecessary. In such case, I shall have no disposition to maintain that hypothesis, as I can have no reason for doing so. It does not, however, appear to me yet proved, that the increase of dip is sufficient to account for the difference in the rate of progress.

With what accuracy the depth of water on the falls can be ascertained from the rate of dip of the strata, or the particular stratum determined, that forms the bed of the fall, I cannot presume under present circumstances to judge.

NOTE — By Professor J. Hall. The points noticed by Professor Gibbes seem to me to be well taken. With regard to the *rate* of recession of the falls, no one can presume to have accurate data. The fact of recession is apparent, and proved by observation and historical records.

The general direction of the chasm or gorge from Lewiston to the Canadian Fall, is in the same direction as the dip of the rock. This will be seen by reference to the map. When the fall was at the line A A, of the accompanying diagram, its

elevation was about the same as the northern margin of the American Fall at the present time. Supposing the strata to have been previously unbroken on the south-west, every yard of recession in that direction would give a greater depth of water over the margin of the fall, by the rate of dip in the rocky bed. The recession in this direction, therefore, giving a constantly increasing depth of water, would give, also, an increased velocity along the slope above the fall, owing to the greater declivity.

Under these circumstances the recession of the gorge, in the direction of the Horseshoe Fall, would continually abstract a portion of the water flowing in the other channel. In order to be convinced of this, it would only be necessary to extend the chasm half a mile further in the direction of the dip to show that no water could reach the American Fall. This may be satisfactorily shown by a diagram.

The character of the upper beds of the Niagara limestone are in general so uniform, that we can scarcely conceive that a greater facility of abrasion is presented in one part than in another. We do not perceive any reason for supposing that the action of the same volume of water could have been more effective, when applied in the direction opposite to the dip, than when applied in an oblique direction. The recession could not have gone on to produce the American Fall, without giving a greater depth and increasing volume of water over the receding Canadian Fall.

If this view be correct, the gradual recession of the Canadian Fall in the direction of F I, is inevitable, since the depth and volume of water must constantly increase as the elevation of the fall decreases, until the whole is drawn to this channel.

It is not impossible that some inequality of surface may produce another fall, on the south side of Goat Island, similar to the American Fall.

It appears to me that the most certain mode of estimating the depth of water on the Horseshoe Fall, would be to calculate carefully the rate of dip in the bed of rock forming the first step in the precipice. This, if accurately measured, for a few hundred yards below the fall, and its rate ascertained, would give the means of ascertaining the amount of dip after passing beneath the water and the farthest point of the fall. With this determined, the elevation of the surface of the water above the face, from any point on this rock below the fall, would determine the depth. The depth of water over the unbroken table rock at the Horseshoe Fall, must be less than fifty feet, and is probably much less than that; while on the American Fall the water is very shallow. This is possibly more than five feet, but if the water were evenly distributed over the entire width of the fall, it would be less than five feet.

One fact should not be overlooked in regard to the resistance and abrasion of the rock at Niagara Falls. It is not by *abrasion* simply, of the upper limestone, that the falls recede. The limestone overlies a soft calcareous shale, which is easily affected by moisture and frost; and the erosion of this shale is constantly in advance of the limestone above, which remains as an overhanging mass, falling in huge masses from its own weight, and the pressure of the water above. This condition is sufficiently shown by the fact that persons walk behind the sheet of water and beneath the overhanging limestone. The support or platform beneath the feet, in this case, is a stratum of limestone beneath the shale, which, in some measure, supports the lower part of the shale, and projects into the water below the level of

the river at the bend of the Horseshoe, and is broken down in masses as the rock above is broken down.

The geological structure is fully explained in the Report of the Fourth Geological District of New York, and in the Journal of the Boston Society of Natural History, vol. iv. p. 106.

So far as regards the points sought to be established in Dr. Gibbes's paper, it appears to me that the first and second are clearly proved; — with respect to the third we do not agree, while the fourth I regard as mainly sustained.

I must still maintain, in opposition to the views of Mr. Desor, that the bed of the Niagara will continue to ascend as the falls recede, at a rate which will preclude for ever any drainage of Lake Erie. It does not appear necessary to repeat here the arguments in favor of this view.

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## 6. On the Broadtop Coal Basin in Central Pennsylvania. With a Map, by J. P. Lesley, of Philadelphia.

The first descriptions published of this small isolated semibituminous coal-field were necessarily very imperfect, mere notices of the fact of coal existing at several points within a radius of eight or ten miles, and of the reason why, namely, the existence of a deep synclinal in the heart of the Upper Silurian region, between Huntingdon on the Juniata, and Bedford Springs. After an examination of two months or more by Mr. Alexander McKinley, in 1838, a short statement of the general outline and supposed subdivision of the field into small parallel troughs, was engrossed by Professor H. D. Rogers in the Annual Report of the Geological Survey of the State; but it was impossible to say at that time, even how many beds of coal it contained, in what way the dynamic geology would develop itself, or what were the actual relationships existing between the carboniferous formation in this outlier, and in the main body of the bituminous coal-field, the edge of which along the summit of the Alleghany Mountains is about forty miles distant. In this condition, the author took up its study in the spring of 1855, and has made a nearly complete survey of the seventy or eighty square miles which it covers. The levels of over nine thousand points upon the mountain have been obtained, and the structure made out with a fair approximation to accuracy. In

another season, the economical operations on the mountain will be so multiplied, that the minutest features of structure will become known, and a complete discussion of the fossils be possible. The present paper is intended to present only the fact and method of my survey, with its three principal results.

1. It has determined that the succession of the measures is not different from the system made out in Western Pennsylvania and Eastern Ohio. There is a base of Carboniferous conglomerate lying upon the Red Shale, from one to two hundred feet thick, massive, homogeneous, ferruginous, seldom conglomeritic, except as a whole, but always in certain of its layers, much of it oblique in deposition, and presenting magnificent expressions of a cleavage nearly vertical, which often completely masks the stratification.

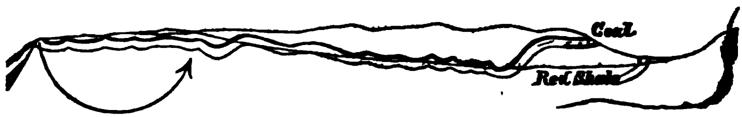
Over this is the series of lower coal beds, then the barren measures, and over all the Pittsburg coal bed, the beginning of the upper series. The purple shales of the barren measures are, however, wanting, their place being supplied by ferruginous sandy shales.

The coal beds are mostly identified with those of the head waters of the Ohio, not by limestone companions, for these are almost entirely absent, nor by beds of iron ore, which are rare, and on which, at any rate, little reliance can be placed, — but by their order in the series, by certain general characters, and by their relations to the two conglomerates, the one at the base of the whole system, and the other at the base of the middle member of the barren measures, a rock as wide spread as the true conglomerate, and known as the Mahoning Sandstone. In the heart of this rock is a workable coal bed, and between it and the lower conglomerate two others, with four or five smaller beds. The larger beds are from five to ten feet thick; the lesser ones from one to three. In the barren middle series, which is four hundred feet thick, are several very small seams of carbonaceous matter. The Pittsburgh coal, and two hundred feet of the upper coal series, with no workable beds as yet known, but with one thin limestone, the representative of the limestone of Greensburg, (there eighty feet thick,) occupy the four geologically highest summits of the basin, the whole thickness of coal-measures in which is about nine hundred feet.

2. The structural results of the survey are interesting, for they exhibit in cross section the whole basin, seven or eight miles wide,

divided by a main anticlinal into two principal troughs, and these subdivided into numerous narrow synclinals or swamps, by a system of horsebacks, not parallel to it, but traversing the basins at a low angle with their sides, and issuing, as in the Wyoming and other coal-fields, into the Red Shale valleys, through the walls of conglomerate. The larger of these synclinals form north-eastward normal terminal knobs, overlooking the great Red Shale valley of Troughcreek, but southwestward flatten out along the crest of conglomerate, which runs very obliquely across them. Their strength, however, in the Red Shale has yet to be determined, and I suggest here that I know of no point of detail in structural geology more worthy of elaboration than this very difficult problem: of determining by a sufficient number of thoroughly worked out examples, the law of the changes undergone by our numerous systems of small anticlinals, wherever they pass out from the massive sands into the equally massive but more plastic clay formations. I well remember certain very curious geometrical speculations upon this point, of Mr. James D. Whelpley, nearly twenty years ago, which he was led into by his development of the geology of the Pennsylvania anthracite coal-fields, but which there was no possibility at that time of demonstrating, nor has there been since. I believe that the discovery of this law will be in a good degree the settlement of the question, whether the wave theory of H. D. Rogers, or the pressure theory of Elie de Beaumont is to be adopted.

In this connection the curves of a broadtop cross section are very significant. Looking south-west they appear thus:—




It will be at once perceived, that the *steep* slopes are commonly *opposed* to the *normal* direction; that is, face the south-east instead of the north-west, and to my eye, present every evidence of an origin purely compressive, and not of an origin due to fluid progression in either direction. In the Terrace mountain alongside, we have the only instance of overturn to the east which I remember to have seen. I believe that in this matter of the normal curve, we have been much misled by making our sections too large, by not measuring them care-

fully enough, by omitting the smaller flexures, or fusing them into the larger ones, and by allowing the eye to be captured by the grander features of the waved line which has thus fallen fancifully into rythmical sequences and series of advancing waves. Every continuous Appalachian cross section should be not only carefully measured in all its dimensions, but reduced to so small a scale that the genius of its curves from end to end can pass at once under inspection, and be discussed without prejudice.

The abruptness of some of these Broadtop anticlinals, compared with the general flatness and repose is very remarkable, and is to be explained so far as I can see, by nothing but side pressure. No faults have yet been discovered exceeding a foot or two; but crushes, etc. are numerous along the horsebacks. The coal is universally slipped but seldom crushed, and hitherto has been found not only hardest but thickest in the steep dips.

A very interesting fact connected with the formation of coal, requires more positive proof than I can at present give it, namely, that the sulphuret of iron *abounds in the synclinals.* Miners and engine drivers insist upon its truth that where the bed is inclined steeply, the coal is purer, and where it lies flat the coal is soft and comparatively rich in sulphur.

3. The Pre-carboniferous coal-measures beneath the Red Shale, are represented in this region by one or more beds of black slate containing a little coal. The subcarboniferous limestone and iron are also present, but not in much force.

I hope to be able to present at the next meeting of the association, a perfect map of the region, and at least one very large specimen of a vegetable plume, not from the red shale, but from the conglomerate, and some statement of the palæontology of the basin. As yet my attention has been too much engrossed by the details of topography and structure, to pay due regard to any thing else, nor am I competent to utter an opinion worth the consideration of fossil botanists, until the collections which I have begun upon the mountain shall have been studied by those who can arrive at respectable results.

## 7. Notes on the Geology of Middle and Southern Alabama. By Professor A. Winchell, Ann Arbor, Michigan.

During a residence in middle Alabama of something more than three years, I enjoyed occasional opportunities for observation upon the cretaceous and tertiary rocks of that State. By request, I present some of the results of my observations in that geologically interesting region. I cannot promise much that is new, but perhaps the recent developments of the great extent and richness of the cretaceous deposits of the United States will attach some degree of interest to what little I may have to add to previous information in reference to the southern bend of the great cretaceous belt.

My observations in Alabama have extended from Tuscaloosa through the counties of Pickens, Sumpter, Greene, Perry, Dallas, Wilcox, Marengo, Clarke, Washington, and Monroe, in all of which I have travelled by private conveyance, and almost everywhere preserved such characteristic fossils as presented themselves. I have visited all the localities along the Alabama, Tombigby, Black Warrior, and Cahaba Rivers that had been rendered famous by the researches of my predecessors, and have preserved sections of these and many others taken on the spot. I always kept notes in my carriage of every thing observed, and from these I extract what I am about to present. My geological travels have extended to the Carboniferous, Silurian, Cretaceous, and Tertiary formations, but my remarks will be confined to the two latter.

The accompanying geological* map exhibits at once the extent and the results of my observations. The following Section may convey some idea of the geological relations of this part of the State.

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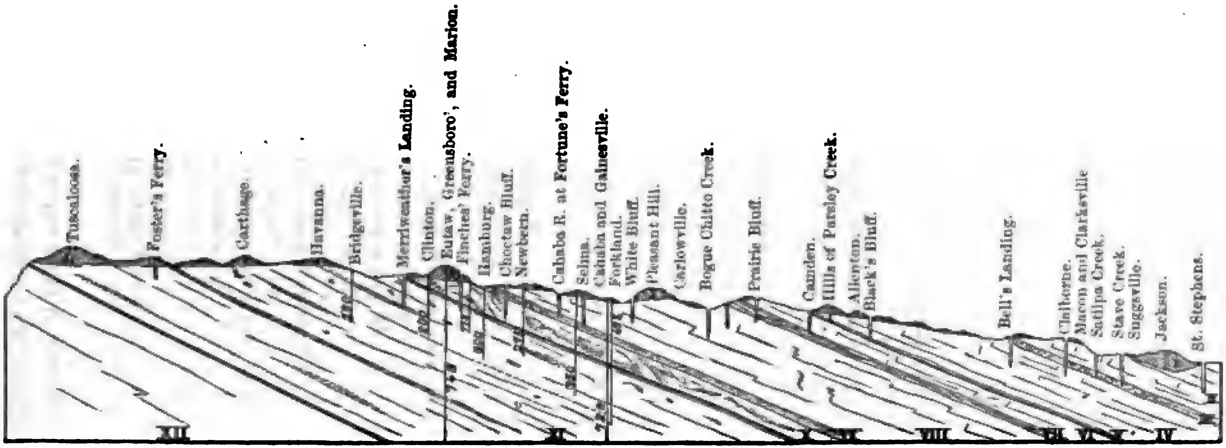
* Not published.




Section from Tuscaloosa to Eutaw, continued from Marion and Selma to Claiborne and thence to Jackson and St. Stephens, exhibiting the stratigraphical but not the geographical relations of the several localities, with true sections in miniature at all the principal Bluffs along the rivers and elsewhere, the whole the result of actual observation. By A. WINCHELL.

REFERENCES.

I. Superficial Materials.
II. White Limestone, } Upper Eocene.
III. Green Sand, }
IV. Buhr Stone, } Lower Eocene.
V. Buff Sand, }
VI. Prairie Bluff Limestone, } Upper Cretaceous.
VII. White Sand, }
VIII. Rotten Limestone, }
IX. Concrete Sand, } Lower Cretaceous.
X. Loose Sand, }
XI. Sand, Clay, and Shale.
XII. Carboniferous Rocks.

The vertical lines drawn across the above section show the location of some of the Artesian wells, with their depths annexed. For a notice of these and others, see paper entitled "Statistics of some Artesian Wells of Alabama."

The following table shows the principal strata which I have recognized, arranged in the order of superposition: —

| | | |
|---|---|---|
| I. | Loam, Pebbles, etc., | Superficial. |
| II. | White Limestone, | Upper Eocene. |
| III. | Green Sand, | |
| IV. | Buhr Stone, | Lower Eocene. |
| V. | Buff Sand, | |
| VI. | Prairie Bluff Limestone, | Upper Cretaceous. |
| VII. | White Sand, | |
| VIII. | Rotten Limestone, | |
| IX. | Concrete Sand, | Lower Cretaceous. |
| X. | Loose Sand, | |
| XI. | Sand and Clay, | |
| XII. | Coal-Measures, | Carboniferous. |
| XIII. | Dark Limestone and Slates, | Silurian. |

Omitting for the present the superficial deposits, I propose to consider, in a descending order, the several strata enumerated: —

1. *The White Limestone.*

I shall not take the time to recapitulate what is already known of this or any of the succeeding strata. The researches of Lyell,* Tuomey,† Conrad,‡ and others have satisfactorily settled the relative age of the bluffs at St. Stephens and Claiborne, but I am not aware that any geologist has noticed anywhere the immediate juxtaposition of the white limestone of St. Stephens, and the continuation of the Claiborne sand-bed. Professor Tuomey, in his "First Biennial Report on the Geology of Alabama," p. 157, says: "It must be recollected that the Claiborne fossiliferous bed is nowhere found in absolute juxtaposition with the overlying orbilulites limestone."

In crossing from Jackson, below St. Stephens to Claiborne, I visited Stave Creek, about four miles north of the main road. This creek has formed high vertical bluffs at the bottom of a very deep ravine. At this place I had the satisfaction of seeing at top, the well known

* Quart. Jour. Geol. Soc. Feb. 1, 1848.
† Rep. on the Geol. of Ala. p. 156.
‡ Jour. Acad. Nat. Sc. [II.] I. 112.

white limestone, full of the characteristic fossils, underlaid by bluish green sand filled with the Claiborne fossils, and at the base, a bed of shale precisely as at Claiborne, but destitute of fossils. On the land of Joseph Chapman also, a few miles west of Macon, (now called Grove Hill,) in Clarke county, some of the branches of the Satilpa Creek have excavated ravines to such a depth that in many places the Claiborne sand bed is exposed, while the white limestone caps the hills above. The sand in these places is quite blue and the fossils are very abundant and well preserved.

The limestone near the top of the bluff at Claiborne is undoubtedly the continuation of the white limestone of St. Stephens and Clarke county; though just at this point its mineral characters are not so well marked. This limestone is seen thinning out near the top of the bluff at Bell's Landing, a few miles above Claiborne. Below is the green sand bed with its familiar forms, while the lower half of the bluff is occupied by the dark shale, seen at the base of the Claiborne bluff. From the sand bed of this bluff I collected uncommonly large specimens of Turritella.

None of the writers on the white limestone, so far as I have observed, make any important distinction between the upper and lower portions. At St. Stephens, it is clearly separable into three sections. At the bottom of the bluff, the limestone is compact, gray, and intersected by firmly concreted bands. The characteristic fossil is *Plagiostoma dumosum.* This stratum has been nowhere else observed. The middle portion of the bluff consists of well characterized white limestone, containing *Pecten Poulsoni, Scutella Lyelli, and S. Rogersi.* The prolongation of this bed to Bettis's Hill, near Suggsville, contains abundance of *Ostrea panda.* The same is true of it at Claiborne. The upper portion of the St. Stephens bluff seems to me to present important points of distinction from other portions of the white limestone. It consists of strata of white hard silicious limestone. It is only in this portion of the bluff that *Orbilulites Mantelli* occurs. These silicious strata are seen capping the hills everywhere in the neighborhood. It is this portion of the bluff which is used for building, and some of the houses of the ancient, though now deserted settlement on the bluff, constructed of this material, are still standing. These same silicious strata are seen capping the hills around Joseph Chapman's, between Clarksville and Macon. They contain here,

besides *Orbitulites*, numerous sharks' teeth and spines of *Echini*, as well as fragments of branching corals. It is seen also on the summit of Bettis' Hill, west of Suggsville, and here contains the same fossils as in the latter place, while the zeuglodon limestone is readily recognized below, containing *Scutellæ*, *Pecten Poulsoni*, and *Ostrea panda*, quite a distinct group. For these reasons I would suggest the possible propriety of recognizing two stages of the white limestone.

### 2. *The Green Sand.*

I adopt this term from Professor Tuomey, though apparently this deposit would be better characterized as blue sand. This is the bed so celebrated by the labors of Conrad and Lea. As already stated, I have observed it in the beds of creeks near Macon, and in the bluff below the *zeuglodon* limestone on Stave Creek. It is also seen by the road side, a few miles east of Suggsville. The color of this sand is decidedly blue in its western prolongation, while toward the east, it becomes gradually more ferruginous, and at Claiborne, it is of a decided buff color. At Bell's Landing above, it is somewhat greenish. The palæontological characters of this deposit are well known, and I have nothing to add at present to previous knowledge. *Crepidula lirata* seems to be one of its most abundant and characteristic fossils everywhere except at Claiborne. *Ostrea Alabamensis* I have not found at Claiborne, while, in the interior of Clarke county, it forms extensive beds. The thick bed of limestone, which underlies the sandy belt at Claiborne, has not been recognized elsewhere. Perhaps its occurrence here is accidental.

Our geologists have generally spoken of the white limestone group as belonging to the Newer Eocene, while the green sand has been placed with the Older Eocene. I would not for a moment maintain an opinion discountenanced by the venerable and accomplished palæontologist, to whom we are so greatly indebted for our knowledge of American tertiary deposits, but I cannot help presenting here for consideration, the fact, that at Stave Creek, where I saw the *zeuglodon* limestone in immediate superposition above the green sand, I was able to trace in it obscure casts of the identical fossils of the latter. Among others which were too indistinct to identify, I saw *Turritella Mortoni* and *Cardita planicosta*. Still, I must admit that these two fossils present a great vertical as well as horizontal range among the

Eocene rocks of Alabama, and their identification alone might not be considered sufficient ground for uniting the green sand to the St. Stephens Group of Conrad.* At any rate, the organic origin of the white limestone is clearly shown by these discoveries.

### 3. *The Buhr-stone Formation.*

Professor Tuomey, in his report already referred to, gives this name to the clayey, sandy, and silicified strata, which occupy the lower portions of the Eocene deposits of the Southern States. I present the observations which I have made upon these deposits in localities not particularly spoken of by others.

In passing from Macon, north-easterly, I saw by the road side and everywhere in ravines, about six miles from Lower Peach Tree, masses of chert or hornstone filled with silicified shells. These are accompanied by a light-colored clay. Similar beds are seen at intervals as far as the Alabama River, on the road towards Camden, but nowhere could I obtain a good view of the extent or mutual relations of these beds. Near the ferry, at Lower Peach Tree, are large masses of calcareous grit, containing *Turritella Mortoni*, *Cardita planicosta*, and other tertiary fossils.

Twenty-five miles east of the Alabama River, on the road from Monroeville to Allenton, I discovered beds of clay and grit, corresponding to those seen west of the river. At eight miles below Turnbull I attained a hill, descending which, I saw scattered along for a quarter of a mile numerous fragments of calcareous grit, very hard, and rendering the road exceedingly bad. In this, were noticed impressions of *Cardita planicosta*, and other fossils. Further down the hill, these gritty beds are underlaid by a fissile calcareous clay or rotten limestone. These beds are similar to what I saw below Lower Peach Tree, but I nowhere saw completely silicified shells.

The country along this road is exceedingly broken and covered with magnificent specimens of *Pinus palustris*. In the bottoms of the valleys, between the ridges, the pine disappears; the woody growth becomes more dense; the *Liquidambar*, the *Fagus*, the *Black Gum*, and superb *Magnolias* are found near the streams, while *Quercus nigra*, *Q. tinctoria*, and *Q. lyrata*, are noticed a little more remote on the ac-

* Proc. Acad. Nat. Sci. Vol. VIII. p. 257.

clivities. The evergreen flora is exceedingly rich. *Ilex*, *Cerasus Caroliniana*, *Gelsenium sempervirens*, and *Magnolia grandiflora*, flourish in the greatest luxuriance and beauty. The streams generally flow over pebbly beds, and the springs and wells furnish sweet and wholesome water.

Above Turnbull I noticed again at intervals, similar beds of calcareous clay or rotten limestone for a distance of eight miles, but I could find nowhere any included fossils. I saw similar beds twenty miles further west, above Black's Bluff. About eight miles from Turnbull, I came upon an areno-argillaceous limestone, somewhat hard, and strewing the road with fragments. I saw in these indistinct casts and impressions of shells. Between six and seven miles from Allenton, this rock comes to the surface, and fragments are strewn over the road for a considerable distance, making it exceedingly rough. A section is also exposed on a small stream near Fox's steam saw-mill. It comes to the surface again at five and a half miles from Allenton. At five miles I saw the rock again in its former soft state, containing more clay and less sand. The oak along here becomes more abundant as the pine diminishes in numbers. At one mile from Allenton, traces of the same rock are again seen near the surface and mingling with the "Red Loam." At half a mile below town, several sections show this rock distinctly in a laminar and scaly state. I traced these beds to town, where I saw fragments of the same mineral composition and firmly cemented, strewn over the surface, and noticed chimneys built of the same hard rock. About three fourths of a mile above Allenton, I discovered the origin of these hard fragments. Here occurs, on the east side of the road to Carlowville, a semicircular depression, surrounded on three sides by a range of hills, making a circuit of nearly a mile. All round the rim of this basin, and near the summit of the hills, is seen a shelf or ledge of rock, curiously projecting and conspicuous. On examination, it proved to be exceedingly hard. Beneath this ledge is a stratum of softer rock, composed of sand, lime, and clay, with scales of mica conspicuously shining. On examining the stratum I observed faint traces of shells for the most part too obscure to be certainly identified, but I could easily recognize casts of *Turritella Mortoni*. Two other casts were doubtfully referred to *Cardium* and *Cucullæa*. A short distance further on I discovered a most interesting outcrop of this sandy stratum consisting here of loose

materials. I was well repaid for a minute search in these sands by the discovery of a group of fossils, on the whole quite distinct from any elsewhere observed. Among them, however, were *Turritella Mortoni*, and others from the Claiborne group. The decidedly strange aspect of the collection, however, renders it probable that this sand represents a distinct stage in the Lower Eocene. The unrecognized species have been left with Professor Tuomey.

The overlying ledge of calcareous grit could be traced to a point eight and a half miles north of Allenton, which is some twenty-five miles further north than the tertiary beds have been hitherto recognized in this part of the State. From this point the landscape had a cretaceous aspect, but the vicinity of my route as far as Carlowville was deeply covered with sand, and I nowhere saw any fossils.

### 4. *Buff Sand.*

The strata of sand, clay, grit, and limestone, described above, are grouped together by Professor Tuomey under the designation of Buhr-stone formation. But I believe he had nowhere to the west of the Alabama River, observed the fossiliferous sand bed spoken of above, as lying at the very base of the tertiary rocks, and embracing shells and Echinoderms, which as a group are so distinct from the Claiborne fossils. It is this bed which, for the sake of a name, I designate as Buff Sand. I recognized it also fifteen miles further west in ascending a hill four miles below Camden. It is here cut through by the highway, and is seen to consist of buff and gray sand, showing oblique lamination, and variously intercalated with thin laminæ of blue black clay. Higher up the hill, it passes into a bed of buff-colored sand, full of fossils in a friable state, — tertiary beyond doubt, but too imperfect for recognition. Beyond this point, and seven and a half miles south of Camden, the same soft argillaceous limestones are seen, as overlie the buff sand between Allenton and Turnbull.

Still further on, in the section at Black's Bluff, I had the satisfaction to see both these beds in juxtaposition above, with cretaceous limestone at the base of the bluff. This bluff (No. 5) consists of red loam and pebbles at the top, which are strown down the sloping declivity. Beneath this is a thick bed of marly clay, soft and finely laminated, presenting precisely the characters of the rock seen between Turnbull and Allenton. Next below is a thin stratum of white

limestone. Next, a thick bed of buff-colored sand, so obscured by detritus from the top of the bluff, that I was unable to explore it. Finally, at the base of the bluff, is a bed of sandy limestone, containing abundance of a species of oyster, which I supposed to be cretaceous.*

The relative position of this bed of buff sand, as observed at Black's Bluff, and in the hill below Camden, shows it to be a prolongation of the sand bed seen above Allenton, and which affords a group of decidedly distinct tertiary fossils. For the reasons above given, I speak of the buff sand as a distinct deposit, older than the buhr-stone of Professor Tuomey, and lying absolutely at the base of the tertiary rocks of the State.

### 5. *Prairie Bluff Limestone.*

This is the limestone exposed at the top of the section at Prairie Bluff (No. 6). I have not been able to identify it certainly with the sandy limestone at the base of Black's Bluff. This limestone at Prairie Bluff is six feet thick, and white. It embraces in its upper part a bed of dark-colored, disintegrated limestone, four feet thick, containing obscure casts of fossils; the lower portion abounds in them, and the base is almost entirely made up of *Exogyra costata* and *Gryphæa mutabilis*, in a very fine state of preservation. Besides these, the following fossils come from this limestone, namely: *Gryphæa convexa*, *Placuna scabra*, *Turritella Mortoni*, *Voluta Sayana*, *Scaphites Conradi*, *Nautilus Dekayi*, three species of *Hamites*, *Pecten 5-costatus*, *Trochus leprosus*, *Plagiostoma gregale*, *Ostrea plumosa* *Echinodermata*, and teeth of placoid fishes. This limestone is well exposed, in a ravine a few rods west of the bluff, as well as at Shell Creek, one mile west. It is also seen in a section made by a stream two and a half miles north. It is exposed by the road side above Carlowville, near the ford over Cedar creek. I have not seen tertiary beds in immediate superposition above this, but I presume the Prairie Bluff limestone is the equivalent of the Black's Bluff limestone, and is the uppermost member of the cretaceous series of Alabama.

### 6. *White sand.*

This deposit immediately underlies the limestone at Prairie Bluff.

* Professor Tuomey has since informed me that he regards this as a tertiary species.

It consists of a bed of loose, light-colored sand, about forty-five feet thick, intersected irregularly by bands of cemented sand. Its most abundant fossils are, *Ostrea larva*, (*falcata*, *Morton*,) *Pecten 5-costatus*, *Gryphæa vomer*. This bed also is well exposed at Shell Creek, and at the stream two and a half miles above the bluff. It is seen near the surface at Rocky Bluff, one mile above, and abounds in the same fossils as before mentioned, though the Pectens are better preserved here than I have seen them elsewhere.

A bed of white sand intersected in a similar manner by concreted bands is seen at the surface, some thirty miles farther east, in the neighborhood of Pleasant Hill. Major Vassar showed me whetstones of good quality, which he had manufactured from these belts of sandstone. I have seen no fossils certainly referable to the sand in this vicinity, but Major Vassar described a fossil which I recognized as *Spherulites*, which is so abundant in the neighborhood, that wagon loads of these, and oyster shells, are often hauled together and burned for lime. I have myself seen magnificent specimens of *Spherulites* collected a few miles farther south; and at Prairie Bluff I obtained valves of *Exogyra costata*, five inches in diameter, and of *Gryphæa mutabilis*, seven inches across.

### 7. *Rotten Limestone.*

I consider the rock at the base of Prairie Bluff, as the uppermost portion of this stratum, though, from its being at present covered with detritus from above, and overgrown with grass, it is difficult to explore it at this place. Being much more coherent than the superincumbent strata, the latter have been denuded during periods of high water, while the silicious stratum at base is left in the shape of a sloping platform. A few miles above Pleasant Hill, on the Selma road, it is beautifully exposed in ravines; and I collected here the largest and best preserved specimens of *Ostrea plumosa* that I have seen. This limestone, with its characteristic fossils, is finely exposed in the cuts made by the Chilatchee and Bogue Chitto Creeks above Prairie Bluff. It is also seen at the high bluff at Centerport, on the Alabama River, where it contains *Cucullæa*. The inclined plane at White's Bluff is cut through this limestone; it constitutes the bluffs at Cahaba and at Selma; and generally, the streams in all this region have formed deep, perpendicular cuts through this limestone. It forms the basis of

the prairie region of this part of the State; and its characteristic fossils were first brought to light by Conrad,* who examined it in the bluff at Erie, and other localities in Greene county. Being well known, I havé nothing to add to the citation of the above localities.

### 8. *Concrete Sand.*

This stratum is well exposed at Choctaw Bluff, (No. 7,) on the Black Warrior river, six miles below Eutaw, in Greene county. I have described this bluff in the Proceedings of the Cleveland meeting of this Association. This stratum consists of sand cemented by carbonate of lime. It nowhere exceeds two or three feet in thickness, but in consequence of its uniform occurrence everywhere beneath the rotten limestone, I describe it as a separate stratum. At Choctaw Bluff, and in many other localities, it is little else than a compact mass of *Ostreidae* and fish teeth. The section at Fortune's Ferry, on the Cahaba river, may be mentioned as very similar to that at Choctaw Bluff, though sixty miles distant. Half a mile east of the village of Hamburgh, Perry county, is also a locality where this stratum crops out, and is an excellent place for the collection of shark's teeth.

### 9. *Loose Sand.*

This is a bed of yellowish gray sand, fifteen feet thick, at Choctaw Bluff, and much thicker at Finches' Ferry, a few miles above, where it occupies the upper portion of the section. It is not rich in fossils, but at Choctaw Bluff it abounds in fossil drift wood often completely riddled by the fossil *Teredo tibialis.* Professor Tuomey † states, that at Finches Ferry he has found *Ammonites Delawarensis* in this stratum.

### 10. *Sand and Clay.*

The bed of loose sand at Choctaw Bluff and elsewhere, is underlaid by a few inches of green sand of variable thickness. In the ravines at Mesopotamia, in Greene county, this green sand is advantageously studied. I have found here, between included laminæ of dark shale, the remains of vegetables appearing like the stems and

* Morton's Synop. Organ. Rem. Cret. Group U. S. p. 21, etc.
† Report on the Geology of Alabama, p. 118.

leaves of dicotyledonous plants. Still lower in the series we find strata and thin laminæ of dark pyritiferous shale, alternating with very thin seams of green, gray, and ferruginous sand. These alternations are well seen at the base of the bluff at Finches' Ferry, (No. 8,) and throughout the whole extent of the bluff at Merriweather's Landing, a few miles higher up the river. The obscure remains of vegetables occur everywhere in the scanty seams of sand throughout this series. The same strata are frequently exposed in the cuttings for the highway between Eutaw and Tuscaloosa.

At about eight miles above Eutaw, the shale becomes softer, the lamination disappears, and we have beds of light clay mottled curiously with blue, red, and yellow, reminding one forcibly of the Keuper of the Germans. More than this, we find along the road sides and the margins of ravines in the upper part of Greene county, large masses of red and poikilitic sandstone, exceedingly compact, and used for underpinning buildings. Add to this that very many of the Artesian wells in Greene county, which penetrate these beds, furnish a constant flow of salt water, showing the occurrence of local deposits of salt; while the deepest borings have brought up abundance of quartzose pebbles, and we have four well-established facts compatible with the supposition of the *triassic* age of these beds, without mentioning the occurrence of vegetable remains, some specimens of which appeared to me indistinctly allied to stems of *Equisetites*.

These beds continue without much change to the very suburbs of Tuscaloosa; and a very good section is seen at Foster's Ferry, within a few miles of town.

The almost total absence of organic remains from these shaly and poikilitic deposits, renders the determination of their age extremely uncertain.

I desire in closing, to record my great obligations to Professor Tuomey, for the kindness which he has at all times shown me, and for the facilities which he has afforded me for the study of the geology of Alabama; and to express the hope that the legislature of that State will place it in his power to complete satisfactorily the survey which he has in charge, and to work out the results in as scientific and beautiful a manner as he is now doing, in conjunction with Professor Holmes, for the survey of South Carolina.

8. STATISTICS OF SOME ARTESIAN WELLS OF ALABAMA. By Professor A. WINCHELL, of Ann Arbor, Michigan.

I. THE alternating beds of sand and shale which underlie the well known "rotten limestone" of the cretaceous series of Alabama, comprise the water-bearing strata of the region of the Artesian wells of this State. The general surface of the state gently rises along a line at right angles with the strike of the cretaceous rocks, so that the lower members of the series outcrop at successively higher levels. In the borings for Artesian wells, water is always obtained when water-bearing strata are pierced, whose outcrop is at a higher level than the point of boring. In individual cases, however, the water has failed to rise to the surface in consequence of the local elevation of the site of the well. In such cases, other borings in the immediate neighborhood, being situated at a lower level, have been successful.

The majority of these wells are situated within a few miles of the line of junction of the "rotten limestone," and the subjacent strata. On the limestone side of this line, the depth of the borings increases with the distance of the well from the line, — varying in this manner from one hundred to nine hundred feet and upwards. On the opposite or northerly side of the same line, the depth of the boring varies from two hundred to one thousand feet, in a manner which seems to depend on the local elevation of the place of excavation.

It would be interesting, and perhaps instructive, to enter into a description of the implements and machinery employed in the boring of these wells, but space does not permit.

The geographical and geological positions of a number of wells are given in a tabular form below. In the separate columns are found the depths of the respective wells, the quantity of water discharged, and its temperature at the surface. At the end of the table are found some additional statistics relating to some of the wells.

An examination of the Section on page 83 may help to convey an idea of the geological positions of some of the principal wells enumerated.

## II. Table of Artesian Wells in Middle Alabama.

| No. | Depth. ft. | Gal. w. per min. | Temp. Fah. | Location. |
|---|---|---|---|---|
| 1 | 470 | | 72 | Junction of Main and Water sts. Selma. Limestone. |
| 2 | 380 | 100 | 68 | Main st. N. of No. 1. " |
| 3 | 334 | 40 | 67 | " N. of No. 2. " |
| 4 | 280 | 12 | 67 | Residence of Abner Jones, Esq., Selma. " |
| 5 | 330 | 25 | | " " J. Lapsley, Esq., " " |
| 6 | 409 | 230 | 67¾ | Foundry, Selma; slightly chalybeate. " |
| 7 | 360 | 300? | 67 | Machine shop, Selma. " |
| 8 | 340 | 100 | | Hall's, " " |
| 9 | 350 | 300 | 67 | Russell & Berry's brickyard, E. of Selma; chalybeate. L. |
| 10 | 360 | 300 | 66½ | Harrison's " " Limestone. |
| 11 | | | 67¾ | Blevins and Edwards, Selma. " |
| 12 | 275 | 20 | | Plantation of E. P. Watts, Esq., near Selma. " |
| 13 | 560 | 250 | | " of Freeman King, Esq., 5 m. below Cahaba, on |
| 14 | 560 | 250 | | the E. bank of Alabama River. L. |
| 15 | 728 | 1200 | 77½ | The "Great Well" at Cahaba. L. |
| 16 | 90 | | 64 | Finches' Ferry, Greene Co., above margin of Limestone. |
| 17 | 258? | | 68¼ | Johnston's mill, Finches' Ferry. |
| 18 | 285 | | 64¼ | Dr. Wither's mill, Greene Co. L. |
| 19 | 360 | | 65 | " " " " |
| 20 | 415 | | 68 | Boligee, " " |
| 21 | 420 | | 66 | Dr. Wither's mill. L. |
| 22 | 468 | | 66½ | " " " |
| 23 | 522 | | 70 | Canefield, Boligee, Greene Co. L. |
| 24 | 560 | | 71 | Capt. Johnston's, Finches' Ferry. |
| 25 | 544 | | 70 | Dr. Perrin's, Burton's Hill, Greene Co. L. |
| 26 | | | 72 | Dr. Clement's, road side, 4½ m. S. of Eutaw. L. |
| 27 | | | | Norwood & Cole, 14 m. S. W. of Eutaw. Highly saline. L. |
| 28 | | | 70½ | Col. Pickens, Warrior river, 4 m. S. " " " |
| 29 | 180 | | 69? | Col. Johnston's horselot, Finches' Ferry, Greene Co., above Limestone. |
| 30 | 420 | | | J. W. Hall's plantation, 12 m. S. of Eutaw. Limestone here about 350 ft. thick, 12 m. from its margin. |
| 31 | | | 70 | Mr. L. Duffin's, Newbern, Greene Co. Highly saline. L. |
| 32 | 294 | 3 | 68¾ | Livingston's, Hamburg, Perry Co. ½ m. above edge of L. |
| 33 | 294 | 20 | 68¾ | Howell's " " " |
| 34 | 330 | 100 | 69 | Weaver's mill, " " " |
| 35 | 352 | 100 | 69 | " " " " |
| 36 | | | | Public well at Eutaw, Greene Co., ½ m. above L. See Remarks. |
| 37 | | | 69¾ | Dr. Clement's 2d well below Eutaw. Saline. L. |
| 38 | 200 | | 67⅜ | Cleaveland's, Springfield, N. of L. Water was reached at 190 feet. |
| 39 | 555 | | 75 | Court House well at Cahaba. L. |
| 40 | 400 | | 73¾ | Bell's (Hotel) well " " |
| 41 | 456 | | 72⅜ | S. L. Creswell's, 10 S. W. of Eutaw, near his house. L. |
| 42 | 440 | | 71 | Well in the field at Creswell's plantation. L. |
| 43 | 550 | | 72½ | Half mile N. of No. 41, Creswell's. L. |
| 44 | 495 | | 72½ | Williamson Glover's, Greene Co. L. |
| 45 | 216 | | 67 | Dr. Childer's, 5 miles W. of Selma. L. |
| 46 | 394 | | | Mr. Strait's, ¾ m. W. of Clinton, above L. |
| 47 | 150 | | | Dr. Cochran's, Sipsey river; above L. |

| No. | Depth. ft. | Gal. w. per min. | Temp. Fah. | Location. |
|---|---|---|---|---|
| 48 | 120 | | | Mr. Craft's; above. L. |
| 49 | 281 | | | Mrs. Barry's; " |
| 50 | 415 | | | Mr. Raspberry's 1st well; above Limestone. |
| 51 | 260 | | | Mr. Campbell's, " |
| 52 | 310 | | | Dr. Brackett's, " |
| 53 | 240 | | | Maj. Whitsett's, " |
| 54 | 276 | | | Dr. Rogers' near the house on his plantation W. of Clinton. Ib. |
| 55 | 400 | | | Dr. Rogers' plantation, Clinton, Greene Co. Ib. |
| 56 | 300 | | | Mr. Smith's; above the Limestone. |
| 57 | 404 | | | Dr. Hutton's; " " " |
| 58 | 280 | | | John Thompson's 1st well. |
| 59 | 300 | | | " " 2d " |
| 60 | 360 | | | At the church in Clinton, Greene Co.; above L. |
| 61 | 348 | | | Maj. Barry's " " " |
| 62 | 340 | | | Dr. Wille's, " " " |
| 63 | 336 | | | Public Well, " " " |
| 64 | 300 | | | Mr. Brown's, " " " |
| 65 | 350 | | | Mr. Copp's, " " " |
| 66 | 310 | | | Mr. Walker's, " " " |
| 67 | 280 | | | Mr. Sears', " " " |
| 68 | 180 | | | Public well at Bridgeville, Pickens Co., above L. |
| 69 | 415 | | | Warsaw, Sumpter Co. L. |
| 70 | 300 | | | Mr. Taylor's, below Warsaw. L. |
| 71 | 380 | | | Peter Ware's, 7 m. W. of Warsaw. L. 1st well. |
| 72 | 360 | | | " " 2d well. |
| 73 | 400 | | | Maj. Whitsett's, W. side of Bigby. L. |
| 74 | 600 | | | D. White's, Cooksville, Noxubee Co. Miss. L. |

### III. *Remarks.*

Nos. 1 to 11. These wells are in and about the city of Selma, within a distance of two miles from the foot of Main (Broad) street. The temperature of *common* well water, taken at the same time with the temperatures of these wells, was sixty-four degrees. The authority for the depths and quantities of water discharged from these wells, is Mr. Crow, who has executed the boring of all the Selma wells, except the one at the foundry, which was bored under the superintendence of Mr. Campbell.

The following is Mr. Crow's statement of the borings of well No. 1:—

| | | | |
|---|---|---|---|
| (1) | Clay, sand, and gravel | 27 ft. | |
| (2) | Blue rotten limestone | 53 " | |
| (3) | Sandstone | 6 " | |
| (4) | Gray sand with water | 6 " | |
| (5) | Blue clay | 18 " | |
| (6) | Blue sticky sand | 24 " | |
| (7) | Blue clay | 17 " | |
| (8) | Green sand | 4 " | |
| (9) | Gray sand with water | 42 " | 5 inches. |
| (10) | Green sandstone | | 11 " |
| (11) | Blue clay | 3 " | |
| (12) | Gray sand with water | 54 " | 3 " |
| (13) | Sandstone | | 7 " |
| (14) | Blue, grayish sand, with water frequent; beds of blue clay 5 to 10 feet thick | 213 " | 10 " |
| | Total depth | 470 " | |

Size of the bore, 6 inches; tubed 400 feet.

It may be interesting to know that the wells, Nos. 2 and 3, were first bored, and that the boring of No. 1 materially diminished the flow of water from the former two. These three wells are within the distance of one third of a mile.

Mr. Campbell, who bored the foundery well, No. 6, and is said to keep a register of all his borings, has furnished for No. 6 the following results: —

| | | |
|---|---|---|
| (1) | "Red loam, clay, sand, and pebbles | 372 inches. |
| (2) | Rotten limestone | 420 " |
| (3) | Soft sand rock ["Loose sand"] | 48 " |
| (4) | Concrete of sand and shells. ["Concrete sand"] | 6 " |
| (5) | Green sand | 24 " |
| (6) | Gray sand and water | 72 " |
| (7) | Hard sand rock | 3 " |
| (8) | Sand and shells | 132 " |
| (9) | 2d hard rock | 9 " |
| (10) | Green sand | 12 " |
| (11) | Rotten limestone. [See below] | 48 " |
| (12) | Blue sand, fine and firm | 288 " |
| (13) | Green sand and water | — |
| (14) | Rotten limestone. [See below] | 180 " |
| (15) | Green sand and water | 84 " |
| (16) | Sticky blue sand and clay | 144 " |
| (17) | Green sand | 36 " |

| | | |
|---|---|---|
| (18) | Gray sand and water | 204 inches. |
| (19) | Green sand | 48 " |
| (20) | Brown sand and water | 60 " |
| (21) | Sand rock | 6 " |
| (22) | Gray sand | 12 " |
| (23) | Sand rock | 36 " |
| (24) | Gray sand and water | 48 " |
| (25) | Green sand | 24 " |
| (26) | Laminated clay | 12 " |
| (27) | Gray sand | — |
| (28) | Green sand and water | 168 " |
| (29) | Rotten limestone, [see below] | 12 " |
| (30) | Gray sand | — |
| (31) | Green sand | 168 " |
| (32) | Rotten limestone, [see below] | 24 " |
| (33) | Gray sand | 280 " |
| (34) | Green sand | 120 " |
| (35) | Rotten limestone, [see below] | 108 " |
| (36) | Spanish-brown colored sand | 72 " |
| (37) | Blue clay and sand | 420 " |
| (38) | Gray sand | — " |
| (39) | Brown sand | 72 " |
| (40) | Green sand and water | 36 " |
| (41) | Gray sand and water | 204 " |
| (42) | Blue sticky clay and sand | 96 " |
| (43) | Sand rock | 25 " |
| (44) | Spanish brown sand | 96 " |
| (45) | Blue sticky clay and sand | 72 " |
| (46) | Green sand and water | 168 " |
| (47) | Gray sand and water | — |
| | Total depth | 409 ft. |

The strata designated as "rotten limestone," in (11), (14), (29), (32), and (35), above, are undoubtedly strata of light colored and perhaps calcareous clay.

The Alabama River rises at Selma in time of flood, 65 to 70 feet. The city stands 10 feet above high-water. The average expense of boring the Selma wells to the depth of 350 feet is not far from 350 dollars. There are now (1853) in Selma and Cahaba, and the intervening country, some 25 or 30 Artesian wells.

No. 12. This is one of the few wells on the east (left) side of the Alabama River. It is nearly opposite Cahaba, and was bored by Messrs. Crow and Read.

No. 15. Mr. Campbell, who bored this well, has furnished the following register of borings: —

| | | |
|---|---|---|
| (1) | Loam, red clay, sand, and pebbles | 394 inches, |
| (2) | 1st. Rotten limestone | 3970 " |
| (3) | 1st. Sandstone (a concrete of sand and shells) | 6 " |
| (4) | Gray sand with water | 36 " |
| (5) | 2d. Sandstone | 15 " |
| (6) | Gray sand | 29 " |
| (7) | Sticky sand and clay | 117 " |
| (8) | Sand and rotten limestone (?) [Clay] | 93 " |
| (9) | Sticky sand and clay | 237 " |
| (10) | Green sand | 18 " |
| (11) | Gray sand with water | 1558 " |
| (12) | 3d. Sandstone | 11 " |
| (13) | Gray sand with water and streaks of rotten limestone (?) | 612 " |
| (14) | Bluish gray sand with two streaks of reddish sand | 384 " |
| (15) | Bluish gray sand and laminated clay | 330 " |
| (16) | Dark gray sand with water | 312 " |
| (17) | Bluish gray sand and clay with water | 716 " |
| | Total depth of well | 727 ft. 11 in. |

and throws out 1,200 gallons of water per minute.

This is truly an astonishing well, but I am sceptical in regard to the alleged quantity of water discharged. Supposing the orifice to be 12 inches in diameter, which I believe exceeds the truth, a discharge of 1,200 gallons per minute would require a velocity of 204 feet per minute, and this velocity by the laws of hydraulics necessitates an ascent of nearly 22 inches; whereas the stream does not rise 12 inches above the mouth of the pipe. As the well, however, is now in a greatly exposed condition, it is not improbable that the bore has been somewhat choked by the mischievousness of boys, whom I have seen throwing brickbats down for amusement. The well was originally bored for the purpose of supplying a steam factory, but is now entirely unemployed.

Nos. 18 to 25. The facts relative to these eight wells are copied from Tuomey's Geological Report. The two at Finches' Ferry, 16 and 17, are beyond the edge of the limestone. "The water is generally highly charged with salts of lime, magnesia, soda, and iron, and in some instances it is impregnated with sulphur." (Tuomey's Report.)

So far as my observation extends, *all* the wells in Newbern, Greene county, are strongly charged with sulphuretted hydrogen. The water from Colonel Pickens' and Dr. Clement's wells (Nos. 26 and 28), and others, are very highly saline.

No. 26. A chemical examination of the water of this well showed it to contain large quantities of chloride of sodium with small additional quantities of salts of lime, magnesia, and iron. The considerable quantity of free carbonic acid present gives the water an unusually lively taste, and it begins to enjoy some little repute as a medicinal water. Indeed, it is difficult to distinguish it by the taste from the celebrated "Congress water."

Nos. 32 to 35. These wells are situated a few rods above the outcrop of the rotten limestone.

No. 36. This well has been more than two years in progress [written in 1853], and though a depth of over 700 feet has been reached, no water has as yet risen to the surface. The situation is just beyond the margin of the "rotten limestone." At less than 100 feet water was reached which came within a few feet of the top. Undoubtedly the failure of this well is owing to the slight elevation of Eutaw above the surrounding country; for, at Judge Evans's, less than half a mile further south, and just over the edge of the limestone, is a successful well though not copious; while at Finches' Ferry, four miles distant, are several copious wells, occupying about the same geological position as the one at Eutaw, though situated at a considerably lower level.

The following statement of the borings of this well has been furnished by John W. Elliott, Esq., the superintendent of the work:—

| | | |
|---|---|---|
| (1) | Soil and red clay | 15 feet. |
| (2) | Sand and soft light colored, mottled clay — last foot laminated | 45 " |
| (3) | White sand and water | 3 " |
| (4) | Blue shale and yellowish clay alternating in thin layers | 200 " |
| (5) | Yellowish clay inclining to red | 130 " |
| (6) | Red, caving soil crumbling like rotten brick | 100 " |
| (7) | Sand (and water) brown, white, and greenish | 20 " |
| (8) | Red and yellowish clay | 100 " |
| (9) | Dark brown sand | 50 " |
| (10) | Coarse reddish sand with gravel and scales of mica | 80 " |
| (11) | Reddish "soapstone" — like bed of clay | — " |
| | Total, August, 1853, | 743 feet. |

No. 41. Diluvial materials here, 11 feet thick; limestone, 200 feet thick.

No. 55. At 140 feet from the surface a hard sand-rock was struck which continued 3 or 4 feet.

Nos. 46 to 74. These wells are mostly situated a short distance beyond the junction of the rotten limestone and subjacent strata. Their depths are given on the authority of Mr. James Strait, well-borer of Clinton, Greene county. The strata penetrated are perfectly similar to those whose statistics have already been given. Generally, in the valley of the Sipsey river, the wells are from 150 to 200 feet deep. At Vienna, at the mouth of the Sipsey, they vary from 350 to 400 feet.

IV. *Increase of Temperature.*

The Artesian wells of Alabama are not particularly adapted to furnishing exact indications of the rate of increase of temperature. As the water generally enters the well at several different points, the temperature of the mixture taken at the top, will always be more or less *below* that of the deepest water reached. The temperatures observed, therefore, in the different wells may vary considerably *below* the true temperature of the deepest seated water, but cannot vary *above* it. Those observations, therefore, which indicate the most rapid increase of temperature are most likely to serve as reliable data.

The mean annual temperature of that part of Alabama over which these wells are distributed, is not far from 64° Fahr., and this is the temperature of ordinary well-water at Selma. The point of constant temperature within the earth's crust has been fixed by different authorities at 50, 60, 70, and 80 feet beneath the surface. As the annual extremes of Alabama are considerable, the point of constant temperature may perhaps with propriety be placed at 80 or 90 feet. Calculating the results from these data, I have formed the following table: —

| No. of Well. | Depth feet. | Temp. Fahr. | Temp. above 64°. | CONST. TEMP. 90 FT. | | CONST. TEMP. AT 80 FT. | |
|---|---|---|---|---|---|---|---|
| | | | | Depth below 90 ft. | Feet for 1 deg. | Depth below 80 ft. | Feet for 1 deg. |
| 1 | 470 | 72 | 8 | 380 | 47.5 | 390 | 48.7 |
| 2 | 380 | 68 | 4 | 290 | 72.5 | | |
| 3 | 334 | 67 | 3 | 240 | 80.0 | | |
| 4 | 280 | 67 | 3 | 190 | 63.3 | | |
| 6 | 409 | 67¾ | 3.75 | 319 | 85.0 | | |
| 7 | 360 | 67 | 3 | 270 | 90.0 | | |
| 9 | 350 | 67 | 3 | 260 | 86.7 | | |
| 10 | 360 | 66½ | 2.5 | 270 | 108.0 | | |
| 15 | 728 | 77½ | 13.5 | 638 | 47.2 | 648 | 48.0 |
| 17 | 258 | 68¼ | 4.25 | 168 | 39.5 | 178 | 41.9 |
| 18 | 285 | 64½ | 0.5 | 195 | 390.0 | | |
| 19 | 360 | 65 | 1 | 270 | 270.0 | | |
| 20 | 415 | 68 | 4 | 325 | 81.2 | | |
| 21 | 420 | 66 | 2 | 330 | 160.0 | | |
| 22 | 468 | 66½ | 2.5 | 378 | 151.2 | | |
| 23 | 522 | 70 | 6 | 432 | 72.0 | | |
| 24 | 560 | 71 | 7 | 470 | 67.1 | | |
| 25 | 544 | 72 | 8 | 454 | 56.7 | 464 | 58.0 |
| 29 | 180 | 69 ? | 5 | 90 | 18.0 | | |
| 32 | 294 | 68¾ | 4.75 | 204 | 42.9 | 214 | 45.0 |
| 33 | 294 | 68¾ | 4.75 | 204 | 42.9 | 214 | 45.0 |
| 34 | 330 | 69 | 5.00 | 240 | 48.0 | 250 | 50.0 |
| 35 | 352 | 69 | 5 | 262 | 52.4 | 272 | 54.4 |
| 38 | 200 | 67½ | 3.5 | 110 | 31.4 | 120 | 34.3 |
| 39 | 555 | 75 | 11 | 465 | 42.3 | 475 | 43.2 |
| 40 | 400 | 73¾ | 9.75 | 310 | 31.8 | 320 | 32.8 |
| 41 | 456 | 72½ | 8.5 | 366 | 43.0 | 376 | 44.2 |
| 42 | 440 | 71 | 7 | 350 | 50.0 | 360 | 51.4 |
| 43 | 550 | 72½ | 8.5 | 460 | 54.1 | 470 | 55.3 |
| 44 | 495 | 72½ | 8.5 | 405 | 47.6 | 415 | 48.3 |
| 45 | 216 | 67 | 3 | 126 | 42.0 | 136 | 44.0 |

Mean, 46.5.

In the fourth column of the preceding table I have given the excess of the observed temperature of the water above 64°. In the fifth column are the depths of the wells below the point of constant temperature, assuming this at 90 feet below the surface; and in the sixth column is the number of feet in depth corresponding to one degree of increased temperature.

Since the higher numbers in the sixth column are, for reasons already stated, most likely to be erroneous, I have entirely rejected those results which exceed 100 feet and also the 29th observation. The general mean of the residue is an increase of temperature of one degree for every 56.7 feet. If we still further reject all numbers in the sixth column which exceed 60 feet, the result obtained is one degree for every 44 96 feet.

If we suppose the point of constant temperature to be situated at 80 feet instead of 90 feet beneath the surface, and employ the same set of observations as last-mentioned above, the rate of increase deduced therefrom is one degree for every 46.5, feet as shown in the seventh and eighth columns of the table.

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## 9. On the Agency of the Gulf-Stream in the Formation of the Peninsula of Florida. By Joseph Le Conte, of Athens, Georgia.

In the winter of 1851, and during the months of January and February, I enjoyed the rare opportunity of visiting and examining the keys and reefs of Florida, in company with Professor Agassiz. I then and there became deeply interested in a subject which has continued to occupy my thoughts from time to time until now; namely, the mode of formation of the Peninsula of Florida.

Until the time referred to, nothing definite was known of the geology of Florida, but it was supposed to consist of a southward prolongation of the eocene of Georgia and Alabama, and its shell-limestone to bear some general resemblance to the white limestone of these States. But the observations of Professor Tuomey,* during the summer of 1850 and the more full and careful observations of Professor Agassiz,† during the following winter, brought to light the remarkable fact that the keys, and the larger portion of the peninsula of Florida are of recent origin, and as far as could be examined, the work of corals — still living in the vicinity, and still engaged in the work of extension — that they are in fact, superficially, at least, the result of the growth of successive coral reefs concentrically arranged, one outside of the other, from north to south. My object in the present paper will be to show that coral agency alone is not sufficient to account for the phenomena, but that there has been another and still more powerful agent at work preparing the ground and laying the foundation for these builders; and that this agent has been the *Gulf-Stream*. A clear understanding

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* Silliman's Journal, 2d Series, Vol. II. p. 393.

† Report of Coast Survey for 1851, p. 145.

of the subject renders necessary a succinct account of the views of Tuomey and Agassiz.

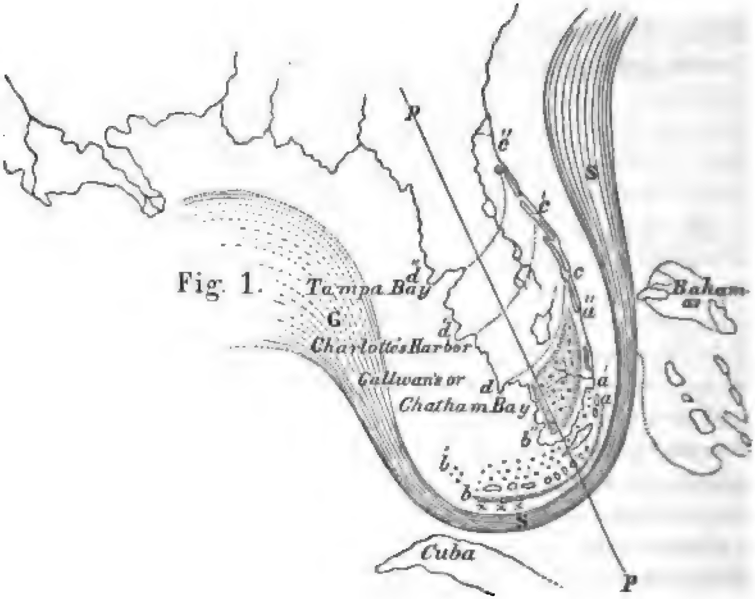



Fig. 1 represents the peninsula and keys of Florida; *a″ b″* the southern coast; *a′ b′* the line of keys, *a b* the line of living reef; *G* ss the Gulf-Stream sweeping around the living reef. Between the living reef *a b* and the line of keys *a′ b′* there is a ship channel varying from five to ten miles in width, and three or four fathoms deep. Between the southern coast *a″ b″* and the line of keys *a′ b′*, a distance at the point *b″* of about forty miles, the water is very shoal, navigable only for the smallest fishing craft, and dotted over with small low mangrove islands. The southern coast is about twelve or thirteen feet above the sea. Within the southern coast, however, we have the everglades, a low swamp but a few feet above the level of the sea, covered with fresh water and dotted over with small islands called hammocks. Beyond, the living reef at the sea bottom slopes rapidly into the almost unfathomable bed of the Gulf-Stream.

Now we have thé best evidence that the everglades, the southern coast, and the keys are all formed by coral agency. The evidence is briefly as follows.

It is a well-known fact that corals cannot grow above the surface of

the water. The islands therefore so commonly formed on coral reefs cannot be formed by the agency of these animals alone, but are due to the violent action of waves breaking off huge coral heads and overturning coral trees, bearing them from the outer and more exposed side and piling them on the middle and inner side of the reef. These coral boulders form the nucleus around which cluster smaller fragments and coral sand; the whole is then firmly cemented by carbonate of lime in solution in the sea-water, and the island thus formed is finally covered with vegetation and inhabited by animals and man.

The whole embryonic development, if I may use the expression, of coral islands may be observed upon the keys and reefs of Florida. On the outer or living reef *a b* some of these commenced to form only a few years ago, exist as yet only in the form of isolated boulders of dead coral, and are not yet dignified with the name of keys. Others are formed of similar boulders mingled with smaller fragments and coral sand, and firmly cemented by carbonate of lime, but the larger boulders are still conspicuous above the surrounding sand though immovably fixed. Still others are so covered with coral sand that the boulders are not observable, except by excavation or by examination of the outermost portion of the island towards the sea. The coral sand is always affected with the cross and oblique stratification so common in materials exposed to the violent action of waves. All the islands on the outer reef *x x x*, are very small, of very recent origin (some only a few years old) and therefore as yet entirely barren.

The examination of the larger and older inhabited islands of the line of keys *a′ b′* proves beyond question that they have been formed in a similar manner. We have here also the same coral boulders mingled with smaller fragments and coral sand, and the whole firmly cemented into solid rock, the same cross or oblique stratification indicating the former action of waves on an exposed shore. The boulders here, also, sometimes stand above the surrounding cement, exposed in their superior portions, as at Key Vaca, and at others completely covered with coral sand, as at Key West and most other keys. This exposure of the larger boulders above the surrounding cement in which they are firmly fixed, led Tuomey into the error of supposing that they were the prominent points of the original reef elevated above the sea level by igneous agency, and that the keys were formed by igneous, rather than aqueous agency. That such is not the case is proved by more attentive examination and comparison with the smaller keys of

the outer reef. There can be no doubt, therefore, that the line $a' b'$ is the position of a former reef changed into keys by the action of waves alone.

In a similar manner it has been pointed out by Tuomey and proved by Agassiz, that the southern coast $a'' b''$ of Florida was the position of still another and an earlier reef. The character of the rock is the same as that of the keys of the main range or of the smaller ones on the living reef. Here also, Tuomey has seen, as he supposes, the evidence of elevating forces, while Agassiz sees nothing but the action of waves.

There seems to be no reasonable doubt, therefore, that at some former period the northern shore of the everglades *c. d.* was the position of the southern coast, and at the same time the present southern coast $a'' b''$ was the position of a reef. The general sequence of changes has been as follows: $a'' b''$ became gradually converted into a line of keys and finally added to the mainland, and the shoal water between $a'' b''$ and *c. d.* became the everglades, and its mangrove islands the hammocks which overdot this swamp. In the mean time, *i. e.*, while $a'' b''$, the present southern coast, was still a line of keys, another reef was formed further out. This became in time converted also in the line of keys $a' b'$, and will eventually be added in its turn to the mainland, and become the southern coast, — the shoal water between $a'' b''$ and $a' b'$ with its mangrove islands becoming another everglade with its hammocks. In the mean time still another reef has been formed yet farther out, namely, the present or living reef $a\ b$, and upon this too, the process of key formation has already commenced. Any farther extension, however, in this direction, by the growth of still another reef, seems precluded by the proximity of deep water. Standing upon the reef, the blue waters of the Gulf-Stream are distinctly seen at the distance of but a few hundred yards.

Thus it appears that not only the keys but the mainland of Florida, certainly as far north as the northern shores of the everglades, has been formed, superficially at least, by coral agency. The evidence in favor of a similar origin for that portion of the peninsula lying north of this line is less abundant, and perhaps less conclusive. Yet we have every reason to believe that the greater portion of this also was formed in a similar manner. Although the geology of this part has not, as far as I know, been examined by any one capable of deciding definitively as to what portion of the peninsula is tertiary and what is recent coral

formation; yet specimens of coral rock precisely similar to that of the southern coast and keys, sent to Professor Agassiz from the shores of Lake George * and other parts of Florida, as far north as St. Augustine, leave no doubt that on the eastern coast at least, the coral formation extends as far north as that ancient city. I have myself a fragment of meandrina from the neighborhood of St. Augustine undistinguishable from fragments which may be picked up anywhere upon the keys. The western shore is still less known, but Conrad and Tuomey state their opinion that the bluffs of Tampa are eocence tertiary.† Supposing this to be a fact, though it is still problematical, then all that portion of the peninsula lying south of the line $c'' \ d''$ is almost certainly of coral origin and formed in the manner already indicated, namely, by the growth of successive reefs. As to the position of these supposed reefs we know absolutely nothing. The position of the lines $c'' \ d''$ and $c' \ d'$ has been merely suggested by the succession of bays which indent the western coast. May they not all have been formed like Chatham Bay, by the imperfect filling up of the shoal water separating successive reefs from the mainland?

Such is a brief account of Professor Agassiz' views concerning the mode of formation of the peninsula and keys of Florida. I will now attempt to show that coral agency alone is not sufficient for this purpose; and that the supposition would violate all probability, and contradict all that we know of the laws which govern the growth of these animals.

It is a well-known fact that reef-building corals cannot grow at a greater depth than from ten to twelve fathoms. It is also certain that they cannot grow above the surface of the water at low tide. Thus they are limited in a vertical direction to a space of about sixty or seventy feet. Unless there is subsidence of the sea bottom, therefore, it is impossible that a reef should be more than sixty or seventy feet thick. To this may be added, in the case of coral *islands*, from ten to fifteen feet for materials accumulated above the sea level by the agency of waves. If there is no subsidence, therefore, no coral formation can be more than eighty feet in thickness. Now nothing can be more certain than that there has been no subsidence whatever of the

* Types of Mankind, p. 352.

† Silliman's Journal, 2d Series, Vol. II. p. 393.

sea bottom upon which grow the reefs of Florida; for otherwise the extension of the peninsula by means of coral agency would have been impossible. It necessarily follows, therefore, that the coral formation of Florida, whether upon the mainland, or upon the keys, or upon the living reef, can nowhere be more than seventy or eighty feet thick. In other words it is evident that Florida and the keys are only faced or incrusted with coral formation. If then corals have been the only agents in this work; if the sea bottom has remained substantially unchanged during the whole time the coral work was progressing, it is evident that the sea for the enormous distance of five degrees of latitude, namely, from St. Augustine to the present reef was nowhere more than sixty or seventy feet in depth, and Florida must have been represented by a tongue of shoal water three hundred miles in length; a circumstance possible certainly, but so improbable, that it behooves those who maintain the theory that corals alone have formed the peninsula to account for it. But even if we admit the probability of such a condition of things, we do not get rid of the main difficulty, for in that case there is no apparent reason why the corals should not grow over the whole area at the same time, as an immense coral forest instead of in the form of successive reefs. In a word, the fact that the corals grew in the form of *successive* reefs concentrically disposed from north to south proves, as it seems to me, incontestably, that the conditions necessary for coral growth have also been progressively formed in the same direction. The horizontal extension of corals through so great a space proves also the progressive extension of the necessary conditions; in other words proves that the sea bottom has been gradually rising from the north towards the south.

Such a gradual rising of the sea bottom may be attributed to one of two causes, namely: first, gradual elevation by igneous agency; and secondly, filling up by sedimentary deposit. As we have already seen, Professor Tuomey has thought that there are evidences of such igneous elevation upon the keys as well as upon the mainland, but the more careful observations of Professor Agassiz have satisfactorily explained these deceptive appearances; so that we may now say with confidence that there is not the slightest evidence of such elevation, but much evidence to the contrary. Neither the mainland nor the keys are anywhere higher than may be accounted for by the action of waves, namely, from ten to fifteen feet, and it is inconceivable that this

elevation should have gone on progressively, preparing ground for the growth of successive reefs, without in the slightest degree affecting the contiguous and recently formed land. But this is precisely the mode of action of sedimentary deposit. Sediment cannot, of course, affect any thing but the sea bottom. It is to sedimentary deposit, therefore, that I attribute the gradual rising of the sea bottom from north toward the south, which, as we have seen, forms the necessary condition for the horizontal extension of coral reef through so great a distance.

Having thus shown that sedimentary deposit is almost absolutely necessary for the explanation of the southward extension of the reefs of Florida, let us attempt now to prove that such deposit has in fact taken place under the influence of the Gulf-Stream.

It is a well known law of currents bearing sediment, that, if from any cause their velocity is checked, they deposit a portion of their sediment upon the bottom; but if, on the contrary, their velocity is increased, they abrade their beds and banks. If, therefore, the velocity of a stream is greater on one side than on the other, abrasion will take place on the former and deposit on the latter. Now if such a stream bearing sediment make a sweep or curve, the velocity will always be greater on the outer and least on the inner side of the sweep. Hence there must necessarily be abrasion of the outer bank and deposit upon the inner. Thus in proportion as the outer curve extends by abrasion of the outer bank, the inner curve will extend also by deposit, and the tongue of land around which the sweep is made will grow longer and longer. If this tongue is cut away by artificial means, so as to convert this portion of the stream into a lake, around the outer margin of which sweeps the current, the still water within the sweep will become more and more shoal until it is again converted into a tongue of land. Now this is necessarily true under all circumstances. It makes no difference whether the stream runs between banks of solid matter or between banks of still water. If a stream bearing sediment run through still water, making a sweep or curve, the sediment must deposit principally upon the inner side of the curve, making shoal water at this part; the curve will extend and the shoal water will extend in the same proportion.

Now the Gulf-Stream is such a current. The strong sweep which it makes around the point of Florida is seen in Fig. 1. If, therefore, the Gulf-Stream bears any sediment, the conclusion seems irresistible

that the sweep of the curve has been increasing with the course of time, and that the tongue of land within the curve, namely, the peninsula of Florida, has been extending "*pari passu*" by means of sedimentary deposit. Or, even supposing that the position of the Gulf-Stream has always been the same as at present, and that Florida was once represented by a tongue of still water within the curve; this tongue of still water must have become more and more shoal by sedimentary deposit. I repeat, then, that upon any conceivable theory as to the position of the Gulf-Stream, whether its curve has been increasing or has been always the same as at present, if it carries any sediment, according to the law of currents, there must have been a progressive shoaling of water and making of land within the curve from north toward the south, and consequently a progressive formation of the conditions necessary for the growth of corals and their extension in the same direction. What evidence then have we that the Gulf-Stream does indeed carry sediment?

The Gulf-Stream is supposed to be a continuation of the great equatorial current which stretches across the Atlantic from the coast of Africa, strikes upon the wedge-shaped point of the eastern coast of South America, and divides into a northern and a southern branch. The northern branch uniting with the waters of the Amazon and Oronoco, runs along the coast of South America, through the Caribbean Sea, under the name of the Caribbean current, enters and receives strength in the Gulf of Mexico, from which emerging it sweeps round the point of Florida and along the coast of the United States on its way to the coast of Europe.

Now is it possible that a stream which washes so many shores, which runs through seas into which are poured such enormous quantities of sediment brought down by the largest rivers in the world, is it conceivable that such a stream should carry no sediment? On the contrary, it is well known that the sediment both of the Amazon and Oronoco rivers is carried by this stream and distinctly traceable for several hundred miles. Much of it is doubtless deposited along the coast and in the Caribbean Sea; but "according to Humboldt much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico."* Into the same gulf is also poured the enormous amount

* Lyell's Principles of Geology, p. 328.

of sediment brought down by the gulf rivers, especially by the Mississippi. Out of this gulf, the waters of which are thus highly charged with sediment, comes the Gulf-Stream on its way round the point of Florida. If then this stream mingles at all with the waters of the gulf rivers, it must necessarily carry sediment. That it does thus mingle is proved by the fact mentioned by Lyell,* that drift timber from the Mississippi is carried by this stream to the shores of Iceland and Europe. Now unless we suppose the whole of this sediment to be deposited in the gulf, it must reach, and, by the law of currents already insisted on, be deposited much of it upon the point of Florida. But we have the best reasons for believing that it is not all deposited in the gulf. The distance from the mouth of the Mississippi to the Tortugas is about five hundred miles. Taking the velocity of the Gulf-Stream through the Gulf of Mexico at three miles per hour, it would traverse this distance in about seven days. Now the finest sediment will not sink more than an inch in an hour; but supposing the mud brought down by the Mississippi sinks at the rate of one foot per hour, in seven days it would sink 168 feet. But the depth of the Gulf of Mexico and the Gulf-Stream is much greater than this. Therefore, fine sediment from the Mississippi would even reach the point of Florida, and what was not deposited there would be carried much farther on. We have farther evidence of this in the soundings made by the coast survey off the eastern coast of Florida, and the nature of the bottom which has thus been brought up. It can scarcely be doubted for a moment that the banks of sand and mud found in the bed and on the margin of the Gulf-Stream off the eastern coast of Florida were deposited there by that stream.

But it will be objected that the water of the Gulf-Stream is remarkable for its transparency. This objection, however, will entirely disappear when we consider the difference between rivers and ocean currents. The former are of slight depth and run over rough bottoms, and between banks possessing many inequalities of surface and offering, therefore, much resistance. Hence are generated partial currents upward and downward, to the right and left, which thoroughly

* Lyell's Principles of Geology, p. 721; and Proc. Amer. Ass. seventh meeting, p. 181, and eighth meeting, p. 140.

mix, as if by a sort of ebullition, the waters of the river. It is impossible that matters in suspension or solution should exist in one part and not in another, that is, that sediment should be carried by the deeper strata, while the superficial strata remain transparent. But with oceanic streams the case is quite different. Their great depth and the fact that they are bounded on all sides by still water, in other words, that they run over perfectly even beds and between perfectly smooth banks, cause them to flow without the slightest agitation, and without the ripples and inequalities which mark the currents of rivers. The currents of oceanic streams, therefore, do not in the slightest degree interfere with the natural subsidence of materials in suspension. They are equally as favorable to subsidence as perfectly still water. The surface transparency of the Gulf-Stream, therefore, forms no objection whatever to the supposition that it carries sediment in the deeper strata. Such sediment would necessarily sink beyond observation in the course of a few hundred miles.

After what I have already said, the bare inspection of the following figures will be sufficient to show the application of the theory in the formation of the peninsula.

Figs. 2, 3, & 4 are ideal sections through the middle of the peninsula, along the line $p\ p$ Fig. 1, representing the different stages of the process, and showing how these two agents concurred in the formation of the peninsula. In all the figures $l\ l$ is the sea level, $G\ S$ the Gulf-Stream, $c$, $a''$, $a'$, $a$, sections of the lines $c\ d$, $a''\ b''$, $a'\ b'$, $a\ b$ of Fig. 1. In fig. 2, $c$ represents the southern coast of Florida, at some time previous to the present elongation of the peninsula, that is, when it was in the present position of the northern shores of the everglades; $c\ n''\ o''$ the sea bottom at that time sloping into the Gulf-Stream, $G\ S$, $n''$ the point where the depth of sixty feet is attained. At this point grew a reef ($a''$), leaving a ship channel $e$ between itself and the southern coast ($c$). Fig. 3 represents the condition of things when by sedimentary deposit the sea bottom had become $a''\ n'\ o'$, the reef ($a''$) had become a line of keys, the ship channel $e$ had become shoal water dotted over with mangrove islands (not here represented), and another reef ($a'$) had formed at the limiting depth of sixty feet, and another ship channel $e'$ between it and the previous reef. Fig. 4 represents the condition of things when the sea bottom had advanced to $a'\ n\ o$. Now $a''$ the line of keys of

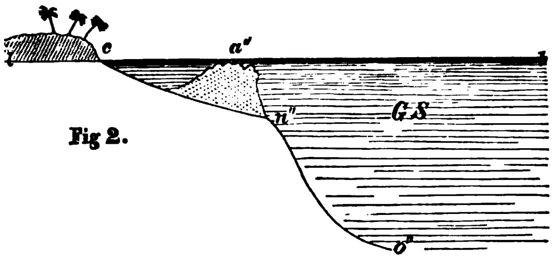



Fig 2.

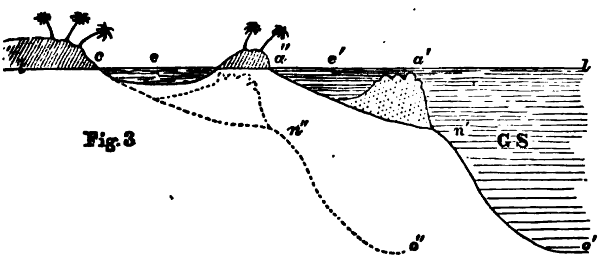



Fig. 3

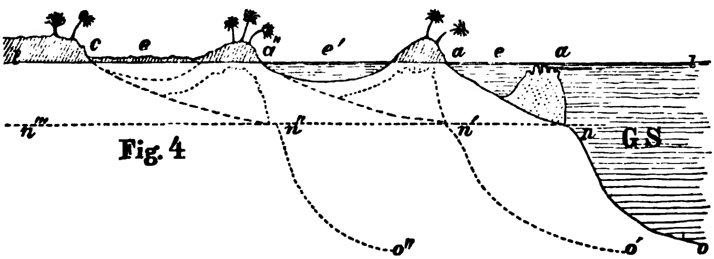
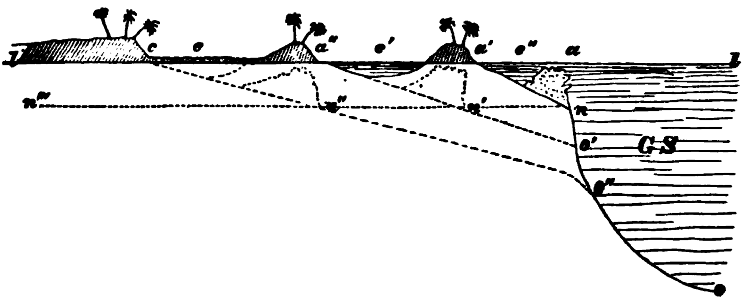



Fig. 4

the last figure has become the southern coast, and the shoal water *e* has become the everglades $a''$, the reef of the last figure has become a line of keys, and its ship channel $e'$ shoal water, and at the limiting depth of sixty feet still another reef *a* with its ship channel $e''$ has been formed. This figure, therefore, represents the present condition with the supposed former conditions in dotted outline.

It is evident that if this theory be correct, and no insuperable obstacle is interposed, the Gulf-Stream may continue to move its bed and the point of Florida to extend almost indefinitely. But such an obstacle is interposed in the island of Cuba. The Gulf-Stream cannot move much beyond its present position, nor Florida extend beyond the position of the present reef, except at the expense of Cuba and the Bahama Banks. Cuba can never be annexed by any natural agencies whether coral or current.

Or even supposing (as I have already done) that the position of the Gulf-Stream has always been the same as at present, and that the peninsula of Florida was originally represented by a tongue of still water; yet substantially the same changes would necessarily have occurred. Fig. 5 is an ideal section showing the succession of changes




upon this hypothesis. The letters represent the same things as on Figs. 2, 3, & 4. It is evident that as the point of Florida approached the Gulf-Stream the slope of the bottom would become steeper, and, therefore, the limiting depth would be attained at a shorter distance from shore, the consecutive reefs would be formed nearer and nearer to one another and the intervening ship channels would become narrower. Inspection of Fig. 1 shows that this is actually the case. We have chosen to trace this process only as far as the northern shore of the everglades, because thus far we have the most indisputable evidence of the recency of the formation. But in the same manner we might carry it still farther back in time and northward in space, and represent the successive reefs by which the superficial portions of the rest of the peninsula were formed. In Figs. 4 & 5 the space between $n\,n'\,n''\,n'''$ and $l\,l$,

equal to sixty feet, represents that portion of the peninsula which I have supposed to have been formed by coral agency alone.

There is one other fact of great importance and otherwise inexplicable which receives a ready explanation upon this theory, and which I think, therefore, is strongly confirmatory of its truth. I allude to the fact that the successive reefs are formed at some distance from one another; in other words, that the peninsula is formed by a succession of barrier reefs, instead of a continuous southward growth of fringing reef. The reefs of Florida are in some respects entirely peculiar. Barrier-reefs have heretofore been considered as always the result of subsidence of the sea bottom, and are invariably looked upon as the sign of such subsidence. But in Florida we have barrier-reefs where it is certain there has been no subsidence. We have here, therefore, a new form of barrier-reef. This important fact did not, I am sure, escape the attention of Professor Agassiz, for my own attention was first drawn to it by him; but I have seen no publication in which he has alluded to the fact, nor, as far as I know, has he ever attempted or even thought of a probable explanation. The explanation which I would offer is as follows: —

It is a well-known condition of coral growth that the sea water must be pure and transparent. Corals will not grow, therefore, on muddy shores or in water, upon the bottom of which sediment is depositing. Now it must be borne in mind that while the Gulf-Stream bears sediment in its deeper strata it is superficially transparent, and we have already shown that this must of necessity be the case with ocean streams. Suppose, then, that the matters held in suspension by the waters of the Gulf of Mexico, be of such a degree of fineness that it sinks to the depth of sixty feet by the time it reaches the point of Florida. It is evident that the sea bottom within the curve cannot rise by deposit above this level; for all the sediment is below. A stream bearing sediment in all its strata from bottom to top, such as a river for instance, will make land within the curve, but an ocean stream will only make shoal water within the curve. In the case supposed, where the bottom of the shoal water rises to within sixty feet of the surface, it will cease to secure deposit, and the water will remain perfectly transparent. Here, then, it would seem, we have the conditions necessary for coral growth. It must be recollected, however, that upon a sloping

shore with mud bottom, such as we have supposed always existed at the point of Florida, a fringing reef cannot possibly form, for the water is rendered turbid by the chafing of waves against the mud bottom; but at some distance from shore, that is, where the depth of sixty or seventy feet is attained and where the bottom is unaffected by the waves therefore, the conditions favorable for coral growth would be formed. Here would be formed a barrier-reef, limited on the one side by the muddiness and on the other by the depth of the water.

I have said that a stream running through still water and making a curve would deposit most of its sediment on the inner side of the curve. This is certainly true, but it is a more general expression of the truth to say that a stream running through still water will deposit sediment on both sides just where it comes in contact with the still water and is retarded by it. It would do so for the same reason that rivers which habitually overflow their banks form natural levees on either side, where the rapid current of the river comes in contact with the comparatively still water of the river swamp. It is well known that the natural levees of the Mississippi continue out to sea in the form of submarine banks, evidently formed by the checking of the velocity of the current on either side by contact with the still water of the Gulf. If the current is straight the deposit on both sides will be equal, and thus the stream will form banks for itself. If the stream is curved the deposit will be mostly on the inner side of the curve, as already said. Is it not probable that the Bahama Banks or, at least, that portion of them which lies to the east of Florida may have been formed to a great extent in the same way; that, while the peninsula of Florida has been made on one side, the Bahama Banks have been made on the other. It will be observed that the great Bahama Banks lie off the eastern coast of Florida, and that the Gulf-Stream runs in a narrow channel between them. At the point of Florida the deposit would, of course, be on the inner side of the curve and would go, therefore, mostly or entirely to the extension of that peninsula; but after the stream turns northward and becomes nearly straight, the deposit would be also on the other side, and thus probably have originated these banks. Or, even if we suppose that there originally existed in this position islands or submarine hills which turned the stream around the point of Florida, these have, doubtless, become greatly modified and extended by

sedimentary deposit. Probably, also, even the general form of the Atlantic bottom, very sloping until the Gulf Stream is reached, and then plunging rapidly into an almost unfathomable abyss, forming a deep bed for that stream, may, to some extent at least, be accounted for in a similar manner; for certain it is that a stream running through still water no less than one running over land will make its own bed, only in the latter case by abrasion it cuts out its own channel, while in the former by deposit it builds up its own banks.

This property of ocean streams, namely, that they form banks or ridges where they come in contact with still water, affords a possible and, as it seems to me, even a probable explanation of certain remarkable peculiarities of sea bottom brought to light by recent soundings across the Gulf-Stream.* Commencing from Charleston, the bed of the ocean slopes at first very gently, so that at the distance of fifty miles from shore it attains only the depth of twenty fathoms, and then very rapidly so that in twenty-five miles more it sinks to the depth of seven hundred fathoms or more. At the additional distance of another twenty-five miles, that is, one hundred miles from shore, at the depth of three hundred fathoms is found a ridge rising from unfathomable depth on one (coast) side, and one thousand five hundred feet above the hollow on the other side. At the distance of a little more than twenty miles more is found another ridge five hundred feet high, followed by still another hollow. Farther observations show that the Gulf-Stream is divided into longitudinal bands or streams of warm and cold water, and that the warm bands correspond to the hollows, and the cold bands to the ridges.

Now these ridges and hollows may be conceived to have been formed in either of two ways, namely, by igneous or by current agency. As upon land, valleys are formed either by igneous or aqueous agency; that is, may be valleys of elevation or valleys of erosion; so also in the sea, ridges may be formed by igneous or current agency, that is, may be ridges of elevation or ridges of deposit. In either case there would be conformity between the direction of the ridges and the direction of the current; only, in the one case the current would conform to the ridges, and in the other, the ridges would conform to the current.

* Proc. Amer. Ass. Cleveland meeting, p. 167; and Washington meeting, p. 140. Silliman's Journal, 2d Series, Vol. XXI. p. 34.

remained. The explorations of Lewis and Clarke, of Long, Nicollet, and Fremont gave us the first glimpses of the true structure of the country along their several lines of travel. Fremont brought us to a knowledge of that singular feature in the physical geography of America, — the Great Basin, with its included Great Salt Lake, — and gave us the first reliable knowledge of the structure of the great Sierra Nevada of California and the extended valleys at its western base. But the unknown regions were so vast that these grand contributions to geography gave us, as I have observed, mere lines upon the map, and great spaces remained blank and unknown. The materials were, however, sufficient to authorize extensive generalizations, which map publishers and others rapidly made, not always distinguishing between the known and the hypothetical. The result was, that our maps left us little to desire, all the spaces were filled, and few could distinguish between the true and the fanciful. Thus those persons who have formed a conception of the orography of the great region west of the Mississippi from the ordinary maps have not attained a true idea of its surface or configuration.

The recently completed surveys, made to determine the most practicable railroad route to the Pacific Ocean, have made great additions to our previous knowledge. Indeed, it is believed that such extensive contributions to the geography and natural history of the interior of any country have never before been made in a similar space of time. Eight expeditions were sent out, each having an independent outfit, instructions, and line to survey. They crossed the country near different parallels of latitude, and their routes were selected with reference to the unexplored spaces. In many cases these parties, when in the field, were subdivided, and thus wider or parallel belts were explored. The combined results of these surveys, when plotted on the map of the Territories, fill up nearly all the previously blank spaces, and serve to connect together the results of explorations previously made. The position, direction, and altitude of ranges of mountains not before described have been made known. The direction and position on the map of a part of the Great Colorado and other rivers have been changed; and the boundaries of the Great Basin have been restored to the limits originally assigned by Fremont. The attention of the surveys having been specially directed to the determination of altitudes and grades, and a large number of accurate instruments having been

provided for this purpose, the results have an unusual interest in an orographic point of view. The altitudes of a great number of mountain passes in all of the principal ranges of mountains from the northern boundary line to Mexico have been very accurately determined, and the inclination of the slopes on each side made known. The materials which had been collected at the date of publication of the preliminary reports * were sufficient to permit of the construction of five profiles of the country from the Mississippi to the Pacific. These were reduced to one scale and published on one sheet under the direction of the Secretary of War. With such an accumulation of new material it is not surprising that previously constructed maps, and even the large map published from the Bureau of Topographical Engineers in 1850, which contained much that had not the authority of actual observation, should be found greatly in error.

It is from these new materials, together with the results of previous explorations, that I have prepared the map which is before us, on which I have laid down the principal mountains in black lines. I have attempted to present the trends of the principal ranges as accurately as possible, and to avoid the errors which result from drawing continuous lines of mountains along the water-shed, or divides between streams without regard to the structure or magnitude of different portions of the chain.

The great number and wide distribution of the mountains, and the variety of names under which the same chain is known at different places, make it necessary to consider them in groups, in order to facilitate descriptions and comparisons. We may readily form them into groups by taking advantage of the great geographical features, and indeed, they are already separated by Nature into three great divisions, which may be described in general as follows.

The first group consists of the great line of water-shed between the Pacific and the Atlantic Oceans, commonly known in part as the Rocky Mountains, and extending from the table-land of Mexico to, and beyond the northern boundary.

The second may include the Sierra Nevada of California and its prolongations south into Lower California and north into Oregon and

* Report of Hon. Jefferson Davis, Secretary of War, on the several Pacific Railroad Explorations. *House Doc.* 129. Washington, 1855.

Washington Territories, also all the ranges between this chain and the coast — the Coast Mountains of California.

The third group comprises the numerous and broken ranges lying between the first and second groups; the ranges of the Great Basin and Salt Lake, and along the Gila.

The first group is sufficiently characterized and separated from the rest by being the dividing ridge or crest of the continent from which the waters flow each way into the Pacific and Atlantic. The second is characterized by its lofty and unbroken line of snowy peaks forming a great wall along the Pacific. The third is well separated from the first, by the valleys of the Colorado and Green Rivers on the south, and Snake River on the north; while on the west, it is separated from the second group by the well-defined line of snowy heights of the Sierra Nevada, and further south by the low valley of the Colorado Desert and the Gulf of California.

It will thus be seen that these divisions of the mountains are founded upon geographical distinctions and not on the geological ages or relations of the chains, although it is believed that the same divisions will be convenient for geological descriptions. Two other groups may be formed of the long line of azoic rocks extending north-west from the Great Lakes, and of the Appalachian chain and its extension north through New England and Canada, and thus all the principal chains of the continent will be included.

I now proceed to a description of the leading features of each group.

We find the northern portion of the first group to be comprised of three principal and nearly parallel ranges, — the Rocky Mountains proper, the Bitter Root Mountains, and the Cour d' Alene Mountains. The last two ranges are intersected by the head waters of the Columbia River, but they are very properly referred to this group. The Bitter Root range extends from about latitude 46° to Clark's fork of the Columbia, and is prolonged beyond it to the eastern side of Flat Bow Lake, where it is known by another name; a parallel chain, or possibly a portion of the same, is there called Kootanie Mountains. The Bitter Root range is considered to be more lofty and rugged than the Rocky Mountains, with which it is joined by the dividing ridges between the Bitter Root River and the Jefferson fork of the Missouri. The Salmon River Mountains, further south, may be regarded as connected with these ranges. The Rocky Mountains proper extend, in

our territories, from the boundary in a direction south 20° east, 260 miles, to lat. 46°, where they curve to the south-west, and unite with the Bitter Root range. From this point south, there is but one range, of which however very little is now known, until it unites with the Wind River Mountains, which extend south 40° east for about 170 miles to the depression known as the South Pass. In this range we have the highest point of the group — Fremont's Peak, 13,570 feet in altitude.

From the southern end of this range to the next, there is a wide interval without any mountains. The country is a table-land or gently rolling prairie, but has an elevation of about 7,500 feet. We find on most of the maps published up to this time the representation of a range of mountains east of the South Pass, and extending from the vicinity of Fort Laramie to Fort Union on the Missouri. Recent explorations made by Lieut. G. K. Warren, U. S. Topographical Engineers, show that there is no range of mountains there; the country is a table-land or plateau.

About 140 miles south-east of the extremity of the Wind River range, we find the mountains again extending in parallel ridges towards the south, and inclosing wide rectangular valleys known as the Parks.

The first or Medicine Bow range is nearly coincident in its direction with the Wind River Mountains, and it is separated from a parallel range south-west of it by the head waters of the Platte River. These mountains, south of the Medicine Bow range, as represented upon the maps, display a singular rectangular intersection of the ridges, which is, however, believed to be in great part caused by drawing lines of mountains along the divides. It is most probable that the ridges are nearly parallel, and I have attempted to show what is probably their true structure on the map. These mountains are generally known as the Park Mountains, and extend on the south to the sources of the Arkansas River. Their general direction is north and south, and some of the highest peaks of the group are found there.

South of these Park ranges we find the broken and composite character of the chain still preserved. The ranges are numerous, and known by different names. They inclose long valleys, through which the Rio Grande flows, occasionally breaking across the low points of the ranges, and thus entering several valleys in succession. On the east of the stream we find the Santa Fé, Sandia, Manzana, Organ, and

Hueco ranges; and on the west the San Juan, Chusca, and Sierra Madre. The Sierra Madre diverges from the Rio Grande, a few miles south of the parallel of 34°, and trends about north 20° west until it disappears in the table-lands near the parallel of 36°. The Organ Mountains, on the other side of the river, appear to be more northerly in direction, trending north 14° west. This is about the trend of the Sierra San Juan and the Hueco range. The Santa Fé range and the mountains north as far as the Sangre de Cristo Pass appear to be nearly north and south in their trend. The only range with a north-east trend is found east of the Hueco range, and west of the Pecos River, and is known as the Guadalupe. It trends north 38° east, and may be regarded as a part of the line of north-east and south-west elevations which are found through Texas and Arkansas.

We have thus followed the great chain of mountains forming this group from the British possessions on the north to the Mexican boundary on the south. The length of this great chain, or rather the distance over which it extends in the territory of the United States, is about 1,400 miles. Its general direction may be said to be north-north-west and south-south-east; but, as we have seen, there are several local but decided deflections. The most prominent is that of which the Wind River range forms a part, where the direction becomes about north 55° west. The trend of the Santa Fé range and the Organ range is nearly north and south, while the Bitter Root and Rocky Mountain range proper trend about north 25° west. A well-defined parallelism of ranges is preserved throughout this group, being distinct along the Rio Grande, south of the Park ranges. Here, there are three or more parallel ranges inclosing long valleys.

We can, as yet, form only an approximate estimate of the general elevation of the whole or principal chain, although our knowledge of the height of the passes has been greatly increased. The principal measurements which have been made are presented in the following table.

TABLE OF PASSES.

| Pass. | Range. | Altitude. | Authority. |
|---|---|---|---|
| Marias Pass. | Rocky Mountains. | 7,600 | Stevens. |
| Lewis and Clarke's. | " " | 6,823 | " |
| Cadottes. | " " | 6,044 | " |
| Hell Gate. | " " | 6,000 | " |
| ——— (Kooskooskia River). | Bitter Root. | 7,040 | " |
| South Pass. | Wind River. | 7,490 | Fremont. |
| Bridgers. | | 7,500 | Stansbury. |
| Cheyenne. | Black Hills. | | " |
| (Nameless) | Park Mountains between New and Old Parks. | 9,000 | Fremont. |
| (Nameless) | Park Mountains between Old and South Parks. | 11,200 | " |
| Cochetopa. | San Juan. | 10,032 | Gunnison. |
| Sangre de Cristo. | | 9,396 | " |
| Raton. | Raton. | 7,479 | |
| Albuquerque (San Antonio). | Sandia. | 6,937 | Whipple. |
| Campbell's. | Sierra Madre. | 7,750 | " |
| Camino del Obispo. | " " | 7,946 | " |
| El Paso del Norte. | Organ Mountains. | 3,830 | Parke. |
| Hueco. | Hueco. | 4,811 | Pope. |
| Guadalupe. | Guadalupe. | 5,717 | " |

We see from this table that the altitude of the passes decreases, both towards the north and the south, the greatest height being found in the Park ranges near the parallel of 40°, or at the sources of the south fork of the Platte River.

SECOND GROUP.

The mountains of the second group, at the extreme north near the boundary, are as yet but little known to explorers. It is, however, certain that the extended range of the Cascades has a nearly north and south trend, and is continuous, — broken, of course, by passes and a deep gorge at the Columbia, — from the British Provinces to the California line. This range, throughout its extent, is characterized by a line of lofty volcanic cones, their summits being covered with perpetual snow. The lava which has flowed from them has extended far from their bases, and has covered the greater part of the rocks of the range from view. It is most convenient to regard the Cascade range as terminating at the south at the Klamath River, near the boundary between California and Oregon. The peak of Shasty might, however,

be very properly regarded as a part of the range, it being the last of the series of volcanic cones. This mountain rises north of Pitt River, and is in this way partly isolated from the Sierra Nevada. Its elevation is now estimated to be not less than 20,000 feet.

We do not find the great snowy range, or the Sierra Nevada to be composed of one continuous elevated ridge, forming a sharp snowy crest, as is generally supposed. It is formed of many and nearly parallel ranges which inclose elevated valleys, precisely as in the Great Basin. The northern part of the Sierra is flattened down into broad tablelands or a plateau, hemmed in on both sides by ranges. The plateau in the vicinity of the Madelin Pass is about twenty miles broad, and has average elevation of about 5,000 feet, the ranges on each side rising from 500 to 3,000 feet higher. The plateau is irregular and broken by short ranges, but extends northward into Oregon to Lake Abert, and the numerous small lakes in its vicinity. These lakes, in fact, occupy the lowest portion of the plateau, and a chain of them is formed along the whole crest of the Sierra to its southern end. This constitutes a peculiar and interesting feature of these mountains, and shows the great amount of precipitation on their summits.

The passes through these mountains generally follow the plateaux, and either turn the points of the isolated ridges, or cross them at their lowest point. We find, in passing southward along the crest, that the elevation of these plains increases. This is shown by the observations of those who have searched for locations for a wagon road. Thus, Carson's Pass, and that traversed by Fremont in 1844, are nearly 8,000 feet high, and one, from Sonora to Walker's River is 10,033 feet.

Still further south, the chain commences a deflection to the west, and here, the altitude decreases. The peculiar broken character is, however, preserved, and we find high valleys beautifully wooded with oaks and covered with grass. Here the passes vary from 5,300 feet to 4,000 feet in elevation, the plains being about 3,500 feet. The width of the rocky outcrops is also reduced at the Tejon, to about thirteen miles, and the ridges do not attain an elevation of over 7,000 feet. It here unites with the transverse chain, the Bernardino Sierra, and this may be considered its southern extremity, its northern being at the end of the Cascade range. It thus extends over a distance of about five hundred and seventy miles, and has the average trend N.

27° W. Its northern portion is nearly north and south; its central N. 30° to 35° W.; and its southern end has a remarkable bend to the south-west. We here have a north-east trend, almost the only example west of the Guadalupe Mountains.

The next range, the Bernardino Sierra, or the southern extension of the Sierra Nevada, has an entirely different direction, and makes a sudden and remarkable deflection to the south-east. Indeed, its trend is N. 76° W., nearly transverse to the Sierra Nevada. It is nearly parallel with the adjoining coast, having, in fact, determined its trend, and extends from the vicinity of Point Conception, eastwardly to the high peak of San Bernardino. It forms part of the southern boundary of the Great Basin, and has an average elevation of about 6,000 feet, its highest peak, San Bernardino, being probably over 8,000 feet in height.

Passing still further south in our descriptions, we find the chain again changing its direction at the San Bernardino, or San Gorgoño Pass. From this point southward, high ridges extend uninterruptedly to and beyond the boundary line, and indeed are found throughout the whole length of the California Peninsula. I have described these mountains under the name of Peninsula Sierra. The northern portion of the chain, within the limits of the State of California, appears to trend nearly north and south, (to the observer who stands in the valley of San Bernardino,) but in reality, it deflects westward, and the main direction may be considered N. 23° W., to N. 30° W. for the whole length. The peak of San Gorgoño, the highest peak north of the boundary, is probably 7,500 feet in elevation.

The Coast Mountains of California are included in this group. They consist of many parallel ranges inclosing large and fertile valleys, and thus form a broad belt of mountains along the coast. The ranges south of the Golden Gate are known under many local names; as, for example, San Bruno range, Santa Cruz range, Gabilan range, and Sierra Santa Lucia. The topography of that region is not yet accurately known, and definite and detailed descriptions cannot now be given. It is probable that these ranges do not average over 3,000 or 4,000 feet in elevation. Monte Diablo, the highest peak, near San Francisco, is about 4,000 feet high. North of the Golden Gate, the mountains are higher, and occupy a greater area from east to west. The general trend of the ranges is north-westerly.

We are yet without sufficient data to enable us to form a just estimate of the average elevation of the great chain which forms the second group, but the height of many of the passes is given in the annexed table.

TABLE OF PASSES IN THE CALIFORNIAN CHAIN.

| Pass. | Range. | Altitude. | Authority. |
|---|---|---|---|
| Yakima. | Cascade. | 3,467 | Stevens. |
| Naches. | " | 5,000 | " |
| Snoqualme. | " | 3,500 | " |
| Columbia River. | " | | |
| Madelin. | Sierra Nevada. | 5,667 | Beckwith. |
| Nobles. | " " | 6,346 | " |
| Johnsons. | " " | 6,752 | Goddard. |
| Daggetts. | " " | 6,824 | " |
| Carson (Fremonts ?). | " " | 7,972 | " |
| West. | " " | 9,036 | " |
| Walker's River to Sonora, | " " | 10,133 | " |
| Walkers. | " " | 5,300 | Williamson. |
| Tahechaypah. | " " | 4,000 | " |
| Humpahyamup. | " " | 5,351 | " |
| Tejon. | " " | 5,364 | " |
| Cañada de las Uvas. | " " | 4,256 | " |
| Williamsons. | Bernardino. | 3,164 | " |
| San Francisquito. | " | 3,440 | " |
| Cajon. | " | 4,676 | " |
| San Bernardino or San Gorgoño. | Peninsula. | 2,808 | " |
| Warners. | " | 3,780 | " |

THIRD GROUP.

The mountains which are classed in the third group do not form one long and continuous chain, as in the first and second. The ranges are exceedingly numerous, and are ranged in parallel lines with a general north and south direction over a broad area. As a group, they are most readily considered in their succession from east to west rather than from north to south.

Along and near the parallel of 41° the most prominent or principal range is known as the Wahsatch Mountains. These mountains rise on the eastern side of the Great Salt Lake, and extend towards the south, forming the eastern rim of the Great Basin. Between this range and the Sierra Nevada, there is a constant succession of ridges, which are short and much broken, but are arranged in parallel lines, and gener-

ally trend north and south. Their altitude varies from 1,500 to 3,000 feet above the general surface of the basin. This general surface or succession of slopes and valleys between the ranges, along the parallel of 41°, has an average elevation of 4,500 feet. There is one great swell of the surface about midway between the lake and the Sierra, which is produced by the Humboldt Mountains, the principal range of the basin. It reaches an altitude of nine or ten thousand feet, or two to three thousand feet above the plain, and the summit of the principal pass through it is 6,579 feet above the sea. The range, so far as known, extends from the Snake River on the north to the parallel of 40°, but is probably continued farther south, and is nearly in a line with the Pai-Ute range separating the Colorado from the Great Basin farther south.

On a line westward from Santa Fé or Albuquerque, near the parallel of 35°, we also find in succession, the Mogoyon, Aztec, Aquarius, Cerbat, Ak-mok-ha-bi, and the Pai-Ute ranges. They are all nearly parallel, and have a north-westerly trend. The Mogoyon range exhibits the greatest departure from parallelism, apparently trending in its southern portion towards the east and uniting with the ranges of the first group, along the Rio Grande. The Aztec range appears to be continuous southward, from near the Colorado, to and beyond the Gila to the Mexican line. The Aquarius and Cerbat ranges also appear to commence near the Colorado, and extend to the Gila. The Pai-Ute range is composed of many minor ridges, which form a part of the wall of separation between the Great Basin and the Colorado. This range is connected with the short isolated ridges and ranges of the Great Basin. Still west of the Pai-Ute Mountains, there is a succession of mountain ridges forming a range bordering the Colorado Desert on the east. It appears to trend south-easterly across the Colorado and Gila near their confluence.

It is most probable that all these ranges are connected with, or are in the line of prolongation of, the principal ranges at the north already noticed. Thus, the Humboldt Mountains probably find their southern continuation in the Pai-Ute range, and the Wahsatch in the Mogoyon. It is, however, possible that the southern end of the Wahsatch range trends towards the west, conforming to the curvature of the Colorado, and similarly to the southern end of the Sierra Nevada.

This general notice of the ranges includes only the most prominent

or well-known lines of elevation. An idea of their relations and general direction will be best obtained by reference to the map.

TABLE SHOWING THE ELEVATION AND POSITION OF THE PRINCIPAL PASSES IN THE RANGES OF THE THIRD GROUP.

| Pass. | Range. | Elevation. | Authority. |
|---|---|---|---|
| | Pah-o-tom Mountains, (First range west of Salt Lake). | 6,364 | Beckwith. |
| | Granite Mountains. | 4,666 | " |
| | Pi-ja-ro-ja-bi. | 5,076 | " |
| Goshoot. | Goshoot. | 6,992 | " |
| | Wa-ro-ja. | 6,726 | " |
| Humboldt. | Humboldt. | 6,579 | " |
| Agate. | Quartz Mountains. | 5,441 | " |
| | Pond Mountains. | 4,648 | " |
| | West Humboldt. | 4,141 | " |
| | Cold Spring. | 5,473 | " |
| Passes around the Mud Lakes. | Black Rock Ranges. | 4,079 to 5,473 | " |
| Uintah. | Uintah. | 8,373 | Gunnison. |
| Wahsatch Gap. | Wahsatch. | 7,820 | " |
| Ahmokhabi. | Pai-Ute. | 5,262 | Whipple. |
| San Francisco. | Mogoyon. | 7,472 | " |
| Aztec. | Aztec. | 6,281 | " |
| El Dado. | | 5,183 | " |

Having now described the prominent orographic features of each group, and shown that the first and the second include great chains which are geographically distinct, I propose distinctive names for them by which they may be conveniently known in descriptions, and which will not conflict with the names now applied to any portions of them.

For the first group, it may be said that the name Rocky Mountains is already well known and sufficient for the whole chain which I have described. But this is a local name, and pertains to a small portion only of the great chain,—a portion north of the parallel of 46°. The ranges further south were known by other names long before the name *Rocky Mountains* came into use; and being then within the limits of Mexico, received Spanish names, by which they are now known. Moreover, the great chain extends down into Mexico, and north to the Arctic Sea or from one end of the continent to the other. As it may be said to commence in the south, where it forms nearly the whole

of the great table-land of Mexico, or *Anahuac*, I propose to call it the *Anahuachian Chain.*

For the second great chain which traverses the two Californias, it is thought that a more appropriate name than *Californian Chain* cannot be found. It might with great propriety be called the *Aurian Chain* or *Columbian Chain*, both of these names having been considered, but relinquished in favor of the former, the only objection to which, that occurs to me, being the danger of regarding the chain as confined to the limits of the Californias, while the name is intended to include the Cascade ranges and their northern prolongations.

For the mountains of the third group, I suggest the use of the general appellation *Aztecian Chains* or *Great Basin Chains*, until further explorations shall show us their relations with more detail, and permit more definite divisions to be made.

These names harmonize with the elegant general title proposed for the Alleghanies and their extensions by the Messrs. Rogers; a name which has now passed into general use, and the utility of which is abundantly proved.

The two great chains are each about 1,500 miles in length, within the territory of the United States, but the Californian chain extends along the peninsula 800 miles further south, and the Anahuachian becomes the table-land of Mexico. We find that the greatest breadth of surface covered by the chains is along the parallel of 40° from long. 105° 30′ to 124°, or about 1,200 miles. This, however, includes the elevated table-land at the sources of the Colorado. It will be seen by the map that the breadth decreases towards the north and the south.

In comparing these great chains together, we are at first struck by the general and close parallelism which they exhibit throughout. Even the inequalities or deflections in the course of one chain find their counterpart in the others; as, for example, the east and west trend in the Californian chain at the Bernardino Sierra finds a parallelism in the deflection of the Anahuachian chain, of which the Wind River Mountains are a part. So, also, the peculiar south-western bend of the southern end of the Sierra Nevada, has, to all appearance, a counterpart in the deflection of the southern end of the Wahsatch Mountains along the Colorado River.

These great deflections from the general course of the chains, and especially the great and sudden bends to the west, are peculiar and

interesting features, and are rendered more so by their parallelism, and the probability that they result from the same cause.

The parallelism of the coast line with the mountains is also interesting from its close conformity, showing that, in general, the shores are rocky, the coast line being principally formed by erosion and not by deposition, as may be said of our Atlantic seaboard. We may, also, infer the existence of strong coast currents, which carry away the loose debris of the rocks beaten down and ground together by the waves.

It is an interesting fact, that the most open and lowest passes in the chains, in other words, the greatest and most decided breaks are formed at the angles or points where the greatest deflections or bending of the chains commence. The South Pass between the Wind River and the Medicine Bow Mountains, and the Pass of San Gorgoño or San Bernardino, and the low passes of the Tejon and Cañada de las Uvas are examples.

One of the most important characteristics presented by the mountains is the number of ridges or ranges which unitedly form the great chains. This is best seen in the mountains of the Great Basin and in the Californian chain, although it is strikingly evident in the Anahuachian chain. These ridges are not ranged side by side, but a general and prevailing overlapping position may be observed. Thus each range in succession is found to extend beyond the other. This overlapping character, or distribution *en echelon*, is not a new feature in the composition of mountain chains, but is found in the Appalachians, and is one of the results of the earth's contraction, which according to the theory advanced by several geologists, and ably sustained in this country by Prof. Dana, is the cause of the great plications of the crust. The overlapping is very clearly shown in the Coast Mountains of California, where the ranges reach the coast successively from the south northward. The Bay of Monterey is included between the end of the projection of one ridge into the ocean at Point Pinos, and the side of another which ends much farther north. The same character is seen in the mountains along the Gila River, in the Great Basin, and at many other places. It will be observed that this character is not confined to the minor ridges or ranges, it extends to some of the important ranges, they being found to sustain a similar relation to each other.

This parallelism and overlapping of the ridges reveals to us the fact, that the rocks of that region are folded and crumpled together as in

the Appalachians, and that similar forces have been exerted on them upon a much more grand scale. Instead of one chain we have several, each rivalling the Alleghanies in extent and altitude. The phenomena of plication are not only indicated by the topography, but have been observed in the Sierra Nevada and Coast Mountains of the Californian chain. They are, also, found in the chains of the Great Basin.

We cannot contemplate the peculiar relations of the principal chains, as exhibited on the map, without recognizing the result of the action of two opposing forces.

If we conceive the principal lines of flexure to be meridional, north and south, the folding may be referred to a force or contraction acting in east and west lines, and this may be termed the equatorial contraction. The trends of the ranges show, also, the action of force in another direction; or from north to south, a polar contraction, to which the sudden bends in the long chains of mountains may be referred.

These bends have already been noticed, but may again be enumerated. They are found in the Sierra Nevada, east of the Bay of San Francisco, in its southern portion, where it curves gradually round to the south-west; and in the Bernardino Sierra trending at nearly right angles to the Sierra Nevada. Parallel deflections are found in the Anahuachian chain in the Wind River range, and again they are seen in the Washatch range of the Great Basin chains. Thus all the long chains are bent as if by compression upon the ends, and the action of force exerted at right angles to the force which has produced the prevailing meridional folding is clearly indicated. It is most probable that this force has acted in north and south lines, and we may term it the *Polar* force or contraction. The overlapping of the ridges and ranges is another evidence of this polar contraction. We may, also, refer the great north-west and north-east trends to the interference of this polar force or resistance with the equatorial contraction, the diagonal trends being the resultants of the two forces. This train of thought leads to interesting speculations concerning the gradual cooling and contraction of the crust of the earth, but it is not my intention to follow out the subject at this time.

I have thus endeavored to present a connected view of the principal mountain chains, and some of the conclusions which we may draw from a study of their relations now that we have the principal chains placed with approximate correctness on our maps. We may, also, conclude

that there is not a region where the great dynamics of the earth are recorded on a scale of greater simplicity and grandeur than in our own land between the Mississippi and the Pacific.

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## 11. General Description of the Country adjacent to the Boundary between the United States and Mexico. By Col. W. H. Emory.

The boundary between the United States and Mexico extends entirely across the continent from ocean to ocean. That portion of it which is formed by the Rio Bravo, below the mouth of the San Pedro or Devil's River of Texas, makes a boundary which, in the absence of extradition laws, must always be a source of controversy between the United States and Mexico.

In other respects the boundary is a good one; and if the United States is determined to resist what appears to me the inevitable expansive force of her institutions and people, and set limits to her territory before reaching the Isthmus of Darien, no line traversing the continent could probably be found which is better suited to the purpose.

In this respect it is fortunate that two nations which differ so much in laws, religion, customs, and physical wants, should be separated by lines marking great features in physical geography. The boundary is embraced in the zone separating the tropical from the temperate and more northern regions. Here waters unite, some of which are furnished by the melting of northern snows, whilst those from the south are supplied from mountains watered by the tropical rains. To the north of this zone the showers of the tropics cease to refresh the earth; and within it all the flora and fauna which characterize the northern and temperate regions almost disappear, and are not entirely supplanted by those of the tropics. It is, indeed, a neutral region, having peculiar characteristics, so different as to stamp upon vegetable and animal life features of its own.

The most remarkable and apparent difference between this region and those of the States of the Union generally, and that which perhaps

creates as much as any other one cause the difference in its botanical and zoölogical productions, is the hygrometric state of the atmosphere. For while the plants and animals assume new forms in life, the crust of the earth, the soil, and the rocks, are everywhere familiar and have many types, indeed fac-similes, over the rest of the American continent. It is very arid, but this is, also, the character of all the country north of the tropics, and west of the 100° meridian of longitude, until you reach the last slope to the Pacific, a narrow belt seldom exceeding two hundred miles in width, and sometimes not more than ten. The zone extending from the Gulf of Mexico to the Pacific, embracing the boundary, contains a large proportion of arid lands, yet this dry region is, perhaps, narrower on the line of the boundary than on any portion of the continent north of it within the limits of the United States, and is occasionally refreshed by showers in the summer season, and so far presents an advantage over the arid belt to the north.

A general description of the topographical features of the country along the boundary between the United States and Mexico (traversing the whole breadth of the continent) cannot be made comprehensive without presenting in the same view the great outline of the continent itself.

It is well known, the most extensive feature in the continent is the plateau, or table-land, which traverses this country from the unexplored region of the north, to its southernmost extremity, ranging in width from five miles to one thousand, attaining its greatest elevation in the Andes of South America; its least elevation and breadth on the Isthmus of Panama and in Central America, and its greatest breadth about the parallel of thirty-eight degrees north latitude. On the northern portion of the continent this plateau attains its greatest height in Mexico, where it is ten thousand feet above the level of the sea. Its lowest depression is along the line of boundary, about the parallel of thirty-two degrees north latitude, where it is about four thousand feet above the sea. Thence, it ascends again and preserves an elevation ranging from seven to eight thousand feet, to near the forty-ninth parallel, where it is again depressed. This plateau, both in North and South America, occupies the western side of the continent, and is traversed by ranges of mountains, the highest peak of which in North America is Mount Elias, seventeen thousand feet above the sea; and in South America is Mount Aconoagua, 21,500 feet above the sea. The climatic feature in this plateau, within the United States, is excessive

dryness, and great changes in temperature between day and night, often as much as sixty-five degrees of Fahrenheit.

The principal ranges of these mountains in North America, naming them in the order of their proximity to the coast of the Pacific Ocean, are first, the Cordilleras of California and Oregon, or the coast range of mountains; second, the Sierra Nevada (which, as its name denotes, is a ridge of mountains and craggy rocks covered with snow); third, the Sierra Madre, another range of mountains which were supposed to separate the water flowing into the two oceans; and fourth, the Rocky Mountains.

The idea conveyed by the name, Sierra Madre, is very generally adopted by the Mexicans, yet I doubt very much if any continuous ridge or chain of mountains can be found which separates the waters flowing into the Pacific from those flowing into the Atlantic. I am, also, quite well satisfied that the mountains known as Sierra Madre in New Mexico are not the same range as those known by that name in Chihuahua and Sonora, and that both are distinct from the range west and south of Monterey, of the same name; but the coast range, the Sierra Nevada and the Rocky Mountains, preserve a very considerable continuity throughout the limits of the United States. The coast range follows the generally north-west direction of the beach of the Pacific coast, and for a very considerable distance rises abruptly from the sea. Along the whole coast it is in view of the navigator, presenting an imposing and ever-changing panorama. It may be said to terminate at Cape San Lucas, the southern extremity of Lower California.

It is the slope towards the sea of this range of mountains, which forms the western border of the arid region, and is, in my opinion, the only continuous agricultural country west of the one hundredth meridian. There are many detached valleys and basins affording facilities for irrigation where the cereals, the vine and all the plants which conduce to the comfort of man, are produced luxuriantly; but they form the exception rather than the general rule, and are separated by arid plains or mountains.

The Sierra Nevada, the Cascade range, and the Rocky Mountain ranges, preserve a general parallelism to each other, and to that of the coast range; and, to use a military term, are mostly developed *en échelon*. Commencing at the north they can be traced continuously until we reach to within a few degrees of latitude of the region

of the boundary, where occurs in all except the coast range the remarkable depression in the continent, or rather absence in the continuity of the ranges of mountains hereafter to be described.

The Sierra Nevada, in latitude thirty-three degrees north, branches; one great division uniting with the coast range and forming the elevated promontory of Lower California, and presenting, when figured on the map, the appearance of the letter Y (Tulare valley resting in the fork of the letter); other branches or spurs are thrown off in a south-east direction, crossing the Gila at the mouth and many miles above, and traversing the newly acquired territory in the meridian of Santa Cruz and Tucson. That range, together with the Sierra Madre and the Rocky Mountains, about the parallel of thirty-two degrees, lose their continuous character, and assume what are graphically described in the western country as lost mountains, that is to say, mountains which have no apparent connection with each other. They preserve, however, their general direction, north-west and south-east, showing that the upheaving power which produced them was the same, but in diminished and irregular force. They rise abruptly from the plateau and disappear as suddenly, and by winding around the bases of these mountains it is possible to pass through the mountain system in this region, near the parallel of thirty-two degrees, almost on the level of the plateau. So that if the sea were to rise four thousand feet above its present level, the navigator could cross the continent near the thirty-second parallel of latitude. He would be in soundings of uniform depth from the Gulf of California to the Pecos River. He would see to the north and to the south prominent peaks and sierras, and at times his passage would be narrow and intricate. At El Paso he would be within gunshot of both shores.

Passing to the south of this parallel, in about that of thirty-one degrees, we find the plateau rising rapidly to the table-lands of Mexico; the ranges above described are no longer traceable, and the plateau gives evidence of having been disturbed by tremendous plutonic forces, and the mountains assume a loftier and more rugged and diversified appearance. As I have said before, the Sierra Madre range of mountains cannot be traced distinctly with our present information. The Rocky Mountains near the head-waters of the Rio Bravo throw off spurs which add to the confusion, and makes it difficult to separate this range from that called in New Mexico the Sierra Madre.

It may be a question whether the Rocky Mountain range is not divided by the Rio Bravo; and if so, that which I have designated as the Sierra Madre of New Mexico, will in that case become a spur of the Rocky Mountains. The geological formations to which I shall presently refer, seem to favor this hypothesis. If that hypothesis be true, the Sierra Madre of New Mexico and the Rocky Mountain system are the same, and are only divided by the Rio Bravo. But this is a question which does not affect the general topographical description of the country, and may be disregarded here. What I have described, refers more particularly to the country west of the Rio Bravo del Norte.

The Rocky Mountain system commencing in the north, beyond the source of this river, and beyond the limits of the 49th degree of north latitude, is the distinguishing feature of the country east of that river, until we reach the great plains lying between the base of those mountains and the valley of the Mississippi. The axis of maximum elevation preserves a general parallelism to the Sierra Nevada range. Its principal chain, after passing the 36th parallel of latitude, becomes less elevated, and finally terminates in the Organ Mountains, near El Paso, reappearing again to the south and east, and becoming at last merged with the great mountain masses in Mexico.

Another branch of these mountains diverges about the head of the Pecos, and running south, with unequal elevation, crosses the Rio Bravo, between the 102d and 106th meridian of longitude, forming the great bend in that river, and producing one of the most remarkable features on the face of the globe, — that of a river traversing at an oblique angle a chain of lofty mountains, and making through these, on a gigantic scale, what is called in Spanish America, a cañon; that is, a river hemmed in by vertical walls. These mountains, to the south of the river, expand in width and height, attaining a great elevation in the neighborhood of Monterey, Saltillo, and Buena Vista, and from one side of the Bolson de Mapimi; and it is my impression that these mountains are identical with what is there called, in Neuvo Leon, the Sierra Madre.

A third, but subordinate range, branches from the main chain, about the same parallel as that last described, and terminates in the Llano Estacado, or the Stake Plains, from which issues the Red River, and other rivers of Texas. From the foot of the Llano Estacado, the

country falls sometimes by steps, but most generally by gentle slopes, to the shores of the Gulf of Mexico; the crust only broken in a few places by the washing of streams, and by the protrusion of igneous rocks. This igneous protrusion, composed of greenstone or basalt, is traced from the San Saba Mountain, by the head of the Leona, to Santa Rosa in Mexico, where it unites with the main ridge at an angle of about forty-five degrees. The point where they unite is rich in silver mines. At Santa Rosa, the Spaniards had sunk extensive shafts, and made a tunnel a mile and a half in length, which was not then complete, when the revolution of 1825 broke out, and since then, all extensive operations have been suspended, and the country, rich in minerals and in the production of the cereals, and of the tropical plants, has been a prey to the incursions of banditti and Indians.

It has been observed that these metaliferous rocks generally occur at such places where two systems unite, or where some unusual disturbance or change in the geological structure takes place. Hence, we may expect to find these silver-bearing rocks along the boundary line, where the upheaving force after passing under the bed of the Gila River begins again to reappear to the south.

The remaining mountain feature of North America, the Alleghany, is referred to here only to illustrate by comparison, the mountain system of the western part of the continent. That chain, grand as it is, sinks into insignificance, when compared to those which I have attempted to describe. It is nearly at right angles to the western chain of mountains, is less elevated, and sheds its waters, as is well known, clear on both sides; on the one side into the Atlantic, and on the other into the Mississippi and the Gulf of Mexico. On both sides, the slopes are comparatively gentle, and the soil fertile, and, refreshed by frequent showers, yields in abundance all that contributes to the wants of man; and on the western side of this slope, between it and the desert border of the Rocky Mountains, such an expanse of fertile country exists, as can be found in one body nowhere else on the face of the globe, producing all the fruits of the earth, including those found in every zone, from the boreal regions to the tropics. Persons who are familiar with its character, as most who read this memoir will be, will scarcely be able to comprehend, still less to believe the character given to the more western and less favored regions described in this report. In the fanciful and exaggerated description given by many,

of the character of the western half of the continent, some have been, no doubt, influenced by a desire to favor particular routes of travel for the emigrants to follow; others, by a desire to commend themselves to the political favor of those interested in the settlement and sale of the lands; but much the greater portion, by estimating the soil alone, which is generally good, without giving due weight to the infrequency of rains, or the absence of the necessary humidity in the atmosphere to produce a profitable vegetation; but be the motive what it may, the influence has been equally unfortunate, by directing legislation, and the military occupation of the country, as if it were susceptible of continuous settlement from the peaks of the Alleghanies to the shores of the Pacific.

Between the two most distinctly marked ranges of mountains before described, the Rocky Mountains and the Sierra Nevada, a succession of minor ranges occur, some of which are many hundred miles in extent, while others appear like isolated mountains rising above the general level of the plateau. Most of them preserve a general system of parallelism; others present their lines of maximum elevation, forming very considerable angles with the general direction; and all, when traced upon a map, exhibit lines varying from right lines to every degree of curvature. The whole system, plateau and mountain, seems to have been produced by a succession of forces analogous to each other in direction, but differing in intensity and occurring at long intervals. The prevalence of granite and other unstratified rocks throughout the Sierra Nevada, suggest the probability of its being the oldest range of mountains. The identity of its rocks generally with those of the Alleghany Mountains, mark these two distinct and detached chains as probably contemporaneous. The rocks marking these mountains are the description commonly traversed by gold and copper mines, as is the case in Oregon, California, Virginia, and North Carolina.

Travelling eastward from the Pacific along the bed of the Gila, we encountered similar rocks in a chain of mountains as far east as the Pimo Village. This chain, characterized also by the presence of gneiss, mica, and talcose slate, has been traced as far south as the present boundary, where it crosses the Santa Cruz River, between longitude 110° and 111°; and in that neighborhood we saw everywhere the remains of gold mines, from which the operators had been driven by the Apaches.

Pursuing our course eastward, along the boundary, from the meridian of 111°, we cross the San Pedro, the Guadalupe, and the San Luis range of mountains, in the order in which they are named, the middle range being chiefly characterized by sienitic aggregates, granitic lava, and immense masses of conglomerate or breccia. Precisely the same formation is found in the cañon of the Gila, some distance to the north, about the meridian of what is called in my reconnoissance of 1846, Disappointment Creek. And no doubt, when future surveys shall develop a more minute knowledge of the physical geography of the country, each of these ranges of mountains will find their equivalent to the north and to the south. With the present information, I shall not even attempt to connect them conjecturally.

Hypothetical geography has proceeded far enough in the United States. In no country has it been carried to so great an extent, or been attended with more disastrous consequences. This pernicious system was commenced under the eminent auspices of Baron Humboldt, who, from a few excursions into Mexico attempted to figure the whole American continent.

On the same kind of unsubstantial information, maps of the whole continent have been produced, and engraved in the highest style of art, and sent forth to receive the patronage of Congress, and the applause of geographical societies, at home and abroad; while the substantial contributors to accurate geography have been overlooked and forgotten.

The San Luis range of mountains rises abruptly from the plains about three leagues north of the parallel 31° 20', and as they run south assume by far the most formidable appearance of any range on that parallel west of the Rio Grande. They are called in Sonora and part of Chihuahua, the *Sierra Madre Mountains*, yet they do not fulfil entirely the conditions implied by that term, for I am informed that the waters flowing from their base towards the Pacific coast often take their rise to the east of these mountains, and flowing through chasms impassable for men, falling down the western slope in rapid descent producing sublime and picturesque cascades.

It is not in my power to explore this range to the south, but I was informed by persons worthy of confidence, that throughout its whole extent, as far south as the parallel of Mazatlan, it was impassable for wagons, and there was no probability of ever finding, south of 31° 20′ a

line for a railway. The report of its impracticability for wagons was confirmed by the fact that the camino real (highway) established by the Spaniards to connect Chihuahua and Guymas, makes a great circuit, and passes to the north of 31° 20′, and within what is now the territory of the United States.

This stupendous range of mountains, which drops so abruptly a few miles north of the boundary, as if to make room for the highway which is to connect the Pacific and Atlantic States, no doubt reappears to the north in the neighborhood of the Gila, but our information is not yet sufficient to establish the connection. I am quite satisfied of one thing, however, its equivalent is not to be found in what is called the Sierra Madre in New Mexico. Pursuing our course still eastward, we pass over wide plains bounded by detached ranges of the mountains, of metamorphic and other limetones, associated with igneous rocks, rich in silver and lead, and at El Paso we encounter the western flank of the third great mountain chain, the Rocky Mountains, known in that particular locality as the Organ Mountains, and at intervals of about eighty miles, we cross two other ranges, the Eagle Spring and the Limpia range of mountains. These three chains of mountains appear to be spurs of the Rocky Mountains, and are characterized by the presence of carboniferous limestone, greatly disturbed by igneous protrusions of what Professor Hall characterizes as of "comparatively modern origin." And throughout this whole region, the carboniferous and metamorphic limestone is not unfrequently traversed by rich seams of argentiferous lead ore. Between the San Luis range and the Organ Mountains, the first of the Rocky Mountain range, the metamorphism of the rocks is so complete and the irruptive lines so frequent, and their protrusion above the crust of the earth so detached, it is impossible to say, with our present information, where the one begins or the other ends, or whether they do not all belong to the same system. It is between these two ranges, upon the banks of the Janos River, that we discover the first evidences of that vast cretacious formation which has been traced from the 108th to the 101st meridian of longitude, and as far north as the great Salt Lake, and south to the 25th parallel of latitude. The western limit of this formation, discovered by the boundary survey, is the basin of the Janos River in Chihuahua; and its eastermost limit, San Antonio in Texas. How far it extends north and south has never been ascertained, but it has

been traced in one direction as far as the big Salt Lake of Utah Territory. Granite, and its associated gold-bearing rocks occur sporadically throughout the Rocky Mountain chain and its spurs, but the distinguishing feature, in an economical point of view, is the prevalence of carboniferous limestone with which is found associated argentiferous galena. Silver mines of richness have been discovered, and some of them worked to a limited extent in the mountains about Tucson, at Barrancos, Presidio del Norte, Wild Rose Pass, in the Organ Mountains, and other localities. Gold mines have been worked at the Calabasas on the Santa Cruz River, and in the mountains of New Mexico on both sides of the Rio Bravo. It will not be extravagant to predict the discovery of many localities where silver mines can be worked to advantage throughout the whole region where carboniferous limestone exists, extending on the line of boundary from the great bend of the Rio Bravo, in Texas, to the meridian of the San Luis range. Should this conjecture prove true, we shall have there in abundance the only commodity in which we are now deficient, and for which we are at all dependant upon any other country. Another argentiferous region of exceeding richness, and I think one wholly disconnected from the other, is in the basin west of the Santa Cruz River, between that river and the Gulf of California. Veins of metal were discovered interjected through a coarse sandstone.

I have stated that the eastern portion of the continent, with which we are familiar, is entirely different in its physical geography from the western, and among the distinguishing features of the first was the Alleghany chain of mountains, which sheds its waters clear from the summit to the ocean. That is to say, water once above the surface at any point continues to flow in that position until it reaches tide water. Between the two great chains which I have attempted to describe, occupying the western portion of the continent, there are other chains of mountains so numerous that it is impossible to describe them by word; some are continuous, some are detached ridges, others isolated peaks, rising from the plateau almost with the uniformity and symmetrical proportions of artificial structures. Between them are found basins which have no outlets to the ocean, but are the receptacles of the drainings of the surrounding water-sheds. Of these the most extensive is the Great Salt Lake, in Utah Territory; and the most remark-

able for its historical associations and present importance, is the valley of the City of Mexico.

This succession of basins forms a prominent feature in the Geography of North America, extending two thirds the length of it and quite one third the breadth of it. They belong to what has been appropriately designated as the basin system of North America. Those found near the boundary are Santa Maria, Guzman, and Jaqui, all to the south of the boundary and within the limits of Mexico. The first is fed by the waters of the River Santa Maria, which runs in a northern direction, and Guzman, by the river bearing the several names, Casas Grandes, San Miguel, and Janos, the general course of which is also from the south to the north, and the waters of Lake Guzman and Lake Santa Maria are said to unite in seasons of unusual freshets. The waters of the Rio Mimbres, near the same meridian as Lake Guzman, which take their rise near the Santa Rita del Cobre, run towards that lake, but they disappear in the plain to the north of the boundary before reaching it.

The waters of these Lakes or inland seas are brackish at all times, but in seasons of drought, which last two thirds of the year, they become excessively salt and wholly unpalatable. Their shores are covered with lacustrine deposits, and are usually unsuited to cultivation. The waters of these vast basins are not all locked up however by the mountains. Three great rivers, with their tributaries, have made their way in different directions to the ocean, cutting in their passage gigantic chasms in the mountains; these rivers are the Columbia, the Colorado of the west, and the Rio Bravo. Another river, the Gila, drains this plateau, cutting the mountains nearly at right angles, which although a tributary of the Colorado, joins it near its mouth, and at an elevation so little above the sea that it may in a general description, be considered a separate and independent drainage.

Another feature of this basin system remains to be described, which is also common to all the rest of the mountain regions occupying the plateau and the region lying east of the Rocky Mountains.

Between the ridges of mountains the traveller occasionally encounters vast plains, which, when the sun is above the horizon, producing the phenomena of mirage, presents to him all the appearance of the sea. The plain bounds the view and the line of the horizon is broken

into waves, resembling in appearance the edge of the Gulf Stream when seen from the deck of a vessel ten or fifteen miles distant. The plains are clothed with vegetation of a scrubby growth, incapable of affording subsistence to any but a class of small animals, such as antelopes, prairie dogs, and rabbits; most generally, however, in the southern part of the United States these plains are clothed with a luxuriant growth of Grama, the most nutritious of all the grasses. Sometimes they are destitute of all vegetation, except the Larrea Mexicana, the Yucca, the Cactus, and other spinose plants, and are paved with minute fragments of basalt, agate, and other hard rocks. Occasionally in these plains we encounter sand dunes, called by the Spaniards *Medanos*, extending over a large area of country, and encircling what might at first sight be supposed the shores of dried-up lakes. But an examination of the sand with a microscope of sufficient power dispels this idea. The grains seem to be angular, and are not rounded by the attrition of water. An extensive formation of this kind occurs between the Rio Colorado of the west and the base of the Sierra Madre, and extends many miles along the western coast of the Gulf of California. Another very extensive waste of sand lies to the south of the Arkansas River; a third is traversed by the Platte River, and a fourth which has come under my notice, less in extent, lies to the south of the Rio Bravo in the State of Chihuahua on the road from El Paso to the city of Chihuahua.

The plains or basins which I have described as occurring in the mountain system, are not the great plains of North America, which are referred to so often in the newspaper literature of the day, in the expression "News from the Plains," "Indian depredations on the Plains," etc. The Plains proper is the extensive inclined surface, reaching from the base of the Rocky Mountains to the shore of the Gulf of Mexico, and the valley of the Mississippi, and they form a feature in the geography of the western country as notable as any other west of the 100th meridian of longitude. Except on the borders of the streams which traverse these plains in their course to the valley of the Mississippi, scarcely any thing exists deserving the name of vegetation. The soil is composed of disintegrated rocks covered by a loam an inch or two in thickness, which is composed of the exuviæ of animals and decayed vegetable matter. The growth on them is principally a short but nutritious grass called buffalo grass (*Sesteria Dactyloides*). A narrow

strip of alluvial soil supporting a coarse grass and a few cotton-wood trees, marks the line of the watercourses, which of themselves are sufficiently few and far between. Whatever may be said to the contrary, these plains west of the 100th meridian are wholly unsusceptible of sustaining even a pastoral population, until you reach sufficiently far south to encounter the rain from the tropics. The precise limit of these rains I am not prepared to give; but think the Red River is perhaps as far north as they extend. South of that river the plains are covered with grass of larger and more vigorous growth. That which is most widely spread over the face of the country is the grama or mezquite grass, of which there are many varieties. This is incomparably the most nutritious grass known. South of the Red River also, the plains are not unfrequently covered with a growth of mezquite trees, (*Algarobia*,) of which there are many varieties. This tree varies in size, according to the character of the soil and quantity of rain. It is usually from fifteen to thirty feet in height, crooked, gnarled, and armed with thorns. The wood is hard and full of knots, and is unfit for purposes of carpentry; but in other respects it fulfils many of the economical uses of life. It is excellent firewood, and makes good posts, being very durable. It exudes a gum which is equal to gum arabic, but to the traveller its most important quality is the fruit which it bears, a nutritious bean much relished by animals, and not wholly unsuited to the tastes of man.

The vegetation of the mountain and basin region, while it differs materially in the genus and species of plants according to the locality, possesses, nevertheless, a general similarity which is striking and peculiar. I have described that of the plateau or levels, as consisting of a diminutive growth of shrubs, but as we ascend from these to the height of the surrounding mountains, we pass through a succession of floral products ranging in character according to the elevation to which we ascend, until we reach an Alpine flora. North of the parallel of 32°, this appears at the height of about 6,000 feet above the sea. In situations protected from the winds, we usually find at those heights pines and cedars, and at a less elevation, different varieties of oak. Wherever this region is traversed by watercourses, cotton-wood, and occasionally sycamore, grow on the edges of the streams. There are throughout this region, on the sides of the mountains, growths of pine, oak, and cedar, which are quite extended, and

present a frost-like appearance, but nowhere until we begin to descend the Pacific slope, and get within the influence of the humidity from the ocean, do we encounter timber at all approximating in size or luxuriance of growth, the forest with which we are familiar in the basin of the Mississippi and the eastern slope of the Alleghanies. The Pacific slope, — including the waters of the Sacramento and its tributaries, the Columbia and its tributaries below the Cascade range and Puget Sound and its tributaries, — it is not my intention to describe in this general sketch, further than to say, that refreshed by frequent showers and fogs from the ocean, it presents a different and more inviting picture than the country to the east of it.

It is on this slope that we find that stupendous growth of red-wood, the accounts of which appear almost fabulous. We find here, too, in all that region north of Monterey, considerable adaptation both in soil and climate, to the production of the cereal plants. About Santa Barbara, in parallel 34° north latitude, the mountains run to the sea; thence the coast deflects sharply to the east, and below or south of this point, the trade-winds, which sweep along the Pacific coast charged with humidity for nine months in the year, from as far north as the Aleutian Islands, seem to diminish in force, and finally die away at the lowest extremity of California. The mountain range at Santa Barbara cuts off these humid winds from the land to the south of them; and it is my opinion that on the Pacific slope, beyond this point, and until we reach the region of the tropical rains, no crops can be raised with any thing like certainty without irrigation. Below them the agricultural character of the country is much the same as that of the mountain and basin system, and this character is retained along the coast until we reach the parallel of Mazatlan, where the tropical rains begin to be felt in great force. For the four months (July, August, September, and October) during which I kept a meteorological record at Camp Riley, no rain fell in sufficient quantity to be measured. The mean height of the barometer for that period was 29.853; the thermometer 68.37, and the mean dew point 58°.13.

There are considerable portions of the extensive mountain system which I have attempted to describe, where wheat and rye can be raised without irrigation; but these portions are exceptions to the general rule; and I think I am safe in stating that, as a general rule, throughout this vast region, corn, cotton, and vegetables cannot be produced

without irrigation; and furthermore, the limits of the ground which can be brought under the effects of irrigation are very circumscribed.

The town of El Paso, in lat. 31° 44′ 15″.7, and long. 106° 29′ 05″.4, is considered, and justly so, one of the garden spots of the interior of the continent. A meteorological record was kept at Frontera, a few miles north of this point for two years, by Assistant Chandler, the results of which are embodied in the accompanying diagram. The whole quantity of rain for one year was only 6.4 inches. From this it will be seen how very dry the climate is, and how unsuited for agricultural purposes, according to the notions entertained of farming in the Eastern States. The settlements about El Paso are irrigated by the Rio Bravo, and are happily not dependent upon rains for their fertility.

Whatever population may now or hereafter occupy the mountain system and the plains to the east, must be dependent on mining, or grazing, or the cultivation of the grape. The country must be settled by a mining and pastoral, or wine-making population; and the whole legislation of Congress, directed heretofore so successfully towards the settlement of lands in States east of the 100th meridian of longitude, must be remodelled and reorganized to suit the new phase which life must assume under conditions so different from those to which we are accustomed.

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## II. PALEONTOLOGY.

### 1. On the Geological Position of the Deposits in which occur the Remains of the Fossil Elephant of North America. By J. W. Foster, of Monson, Mass.

The true position in the geological series of the deposits in which these remains occur is still a mooted point among American geologists. Many maintain that the introduction of the elephant upon the earth was subsequent to the Drift epoch, and there are those even who assert that their extinction has taken place since the advent of man. I am disposed to refer their origin to a far higher antiquity, when the earth

was tenanted with different forms of animal life, and when different physical conditions prevailed from what we now behold. I will proceed with some minuteness to adduce the evidence on which this opinion is based; and in the accomplishment of the task it will be necessary to inquire into the origin and age of the superficial deposits in which these remains are entombed.

From the borders of the Arctic Ocean to the limits of latitude forty degrees north, we meet with accumulations of clay, sand, and gravel, interspersed with boulders of northern origin, and blocks derived from no great distance. In the basins of the Great Lakes, these deposits consist of marly clays, variously colored, overlaid by coarse pebbles, and water-worn boulders. Intermingled with these clays are found the remains of vegetables, consisting, so far as identified, of red and white cedar, spruce, pine, and cranberry, — indicating the existence of a sub-arctic vegetation. Thus far, throughout the entire area occupied by these deposits, few remains of shells have been found; but these are of fresh water origin. These materials are sometimes mingled together pellmell, but are more frequently distributed in stratified beds. The boulders occupy no particular position, but appear to have been deposited sometimes upon rubble and sometimes on comminuted clay.

We are too apt to regard the Drift agency as of short continuance; and there are those who still maintain that the materials were distributed by a temporary rush of the waters; but it may be presumed that a long interval of time intervened between the first grooving and planing down of the rocks and the cessation of the boulder transportation, which observers have thus far failed to indicate by distinct geological monuments.

There are other phenomena intimately connected with the close of the Drift epoch, to which I will proceed to advert. These are the TERRACES.

To those who have investigated the terraces which border the great lakes and rivers of our country, it must appear evident that they have not resulted from the bursting of barriers at their outlets, but from the gradual rise of a portion of the continent, with sufficient pauses in the movement to admit of their formation. The oldest river terraces appear to have been formed towards the termination of the Drift period, since we find that they contain erratic and angular blocks which could not have been transported to their present position by

existing agencies. This might not necessarily follow in all instances,—for the Drift of which they are composed might have been subsequently modified by fluviatile action; but we have not the means of distinguishing between primitive and modified drift. Even those terraces composed of comminuted materials might have been formed at a time when the summits of the country were above the Drift agency, while the depressed portions were exposed to its ravages.

On the whole, it is reasonable to suppose that the most ancient of the terraces are intimately connected with the termination of the Drift epoch, and that their formation was the result of those elevatory movements by which the continents were made to assume their present outlines. When we witness the present operation of rivers in eroding their channels and forming alluvial deposits, we may well suppose that the more recent even of the terraces have a higher antiquity than that ordinarily assigned to the introduction of man.

We propose to offer a few remarks as to the physical conditions which obtained during the accumulation and dispersion of the superficial materials comprehended under the head of Drift. It is pretty well agreed among geologists that ice was the agent by which the rocks were planed down and striated, and the boulders transported; but it is not agreed whether that agency was manifested under the form of glaciers or icebergs.

For the production of glaciers several conditions must exist. The country must be diversified with mountains and valleys; the vicissitudes between the summer and winter temperature must be marked; and the atmosphere must be sufficiently charged with moisture to cause it to descend in the form of rain and snow. Hence, at this day, as pointed out by De Beaumont, we have beneath the tropics, mountains which rise above the snow-line; but there is not sufficient variableness of climate to cause the snow to descend in the form of glaciers. Hence, in Arctic America we have all the conditions of climate necessary to their production; but the relief and depression of the soil are wanting.

If we were to suppose that, preceding the Drift epoch, the country stood a few thousand feet higher than at present, the summits of the Adirondack and White Mountains would be brought within the limits of perpetual snow; glaciers might be formed, which, descending into the valleys, would groove and polish the rocks and leave behind long lines of rocky fragments known as moraines. But in the region of the West,—

where, from the southern confines of the Drift to the borders of the Arctic Ocean, there is no elevation two thousand five hundred feet above the tide-level,*—whatever might have been the conditions of the climate, glaciers would not be generated. Immense accumulations of ice would be formed in the circumpolar regions, and a sub-arctic vegetation would cover the plains and the slopes of the hills, where now we meet with deciduous trees.

While, therefore, in the more elevated portions of New England and New York, we find phenomena clearly referable to glacial action, throughout the West, we must resort to other causes to explain the planing and grooving of the rocks, the transportation of boulders, and the stratification of the superficial materials.

That the climate of both continents was much colder preceding the human epoch than at present, is evidenced by a variety of facts. The buried timber, as before remarked, is almost exclusively of a sub-arctic character. The molluscs of this period, according to Prof. E. Forbes, although belonging mainly to existing species, indicate by their assemblage the same thing. The fossil elephant of Europe, by his compound covering of wool and hair, was adapted to withstand the rigors of a northern climate; and by the augmented complexity and number of the triturating plates of his teeth, as compared with the existing species, as indicated by Owen, was adapted to live mainly on the woody fibre of trees. That the habits of the mastodon were similar, is proved by the fact that the contents of his stomach, in several instances, have been found to be composed of twigs and branches of coniferous trees which now flourish in northern latitudes, and which are identical with the buried arborescent vegetation of the Drift.

Assuming that the country was submerged — and that it has been is evidenced by the Drift deposits two thousand feet above the ocean level — the vast accumulations of ice in the circumpolar region would be set afloat, in the form of bergs, freighted with fragments of rock and finer materials incorporated with them while attached to the land, which, entering the water, would pursue a southern direction, for the reason that the cold waters of the north are constantly flowing towards the equatorial regions; nor would their course be modified to any great extent by

* The height of land between Lake Superior and the Arctic Ocean, according to Sir John Richardson, does not exceed 1,500 feet above that lake.

winds, as about seven-eighths of their surfaces must have been submerged. As they melted away in their progress, they would leave behind long trains of boulders, which subsequently, when the sea bottom was elevated, would be found strewn over an unequal surface, or imbedded in detrital materials of variable fineness. These materials, if thrown down in deep water, or exposed to the action of currents, would be assorted and stratified. Wherever the icebergs became stranded upon a reef or shoal coast, the rocks would be scratched and grooved, and long lines of pebbles and boulders would be thrown up. It is by a process like this, in our opinion, that the rocks have been grooved and the boulders distributed.

If now the country were to rise slowly, with occasional pauses in the movement, summit after summit would emerge; the ocean would recede farther and farther, leaving behind a series of coast lines and beaches, indicating its former level; estuaries would become converted into lakes; the superabundant waters would be gathered into the depressions, and the rivers would flow with increased velocity, excavating for themselves new channels and bearing into the pools the silt and sand of a former sea bottom. Terraces would be formed along the margin of the valleys, as the country rose, or the waters cut away the barriers which imprisoned them.

The lakes and pools thus formed might soon become the habitats of numerous fresh water mollusca, whose remains at this day constitute beds of shell-marl. As the lakes shoaled, either by successive depositions of detrital matter or by a lowering of their outlets, aquatic plants, such as the lilies and the rushes, would take root in the bottom, succeeded by the *chara* and the *sphagnum*, which would flourish so long as the lake beds furnished a sufficient amount of moisture. While these changes were taking place on the land, far out in the sea and along the coast lines, the same causes which had dispersed the detrital materials over higher levels might be in full activity. Thus, many of the swamps and peat marshes which have served as the sepulchres of the mastodon, may have originated at a remote epoch, as compared with the advent of man, although the associated shells belong to existing species.

We have, then, evidence of an augmentation of cold by which large icy barriers were formed, of the depression of a vast area in the northern portion of the continent, of the dispersion of boulders, of a subsequent elevation of the land, of the formation of terraces and beaches, and

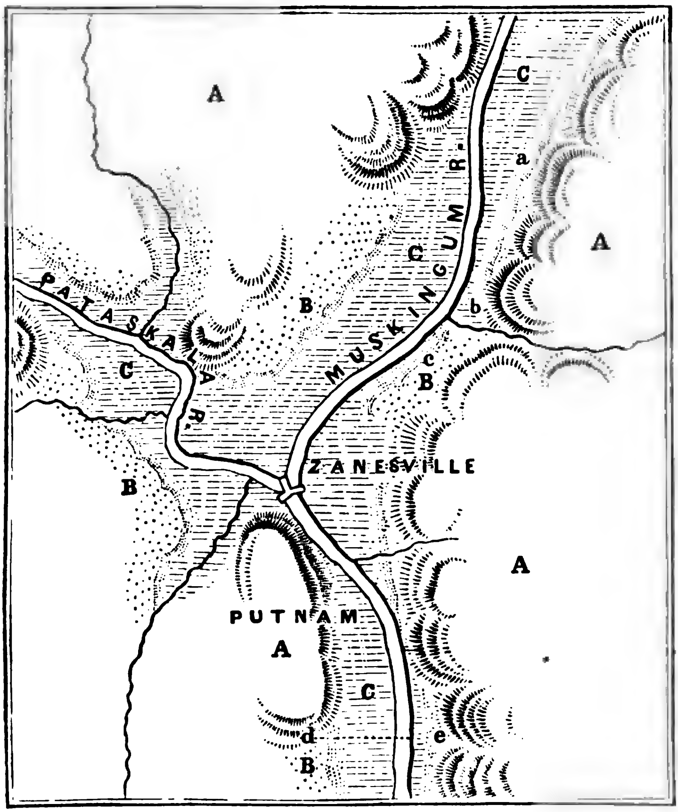
of the deposition of detrital materials, enveloping the remains of terrestrial and molluscous animals.

Having thus endeavored to sketch the peculiarities of the Drift deposits, I will now proceed to notice their connection with the remains of the elephant.

### THEIR OCCURRENCE IN OHIO.

The following topographical sketch of the Muskingum Valley, near Zanesville — which is on a scale of one inch to the mile — will serve to illustrate the relative position of the several formations.

TOPOGRAPHICAL SKETCH OF THE MUSKINGUM VALLEY.



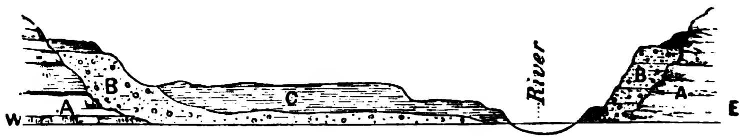
A. Coal Measures.
B. Valley Drift consisting of stratified beds of gravel, sand, and pebbles, with occasional boulders of granite, and angular blocks of limestone and sandstone, inclosing the remains of the fossil elephant.
C. Yellow loam forming the river bottom, or alluvial deposit.
*a, b, c.* The points in the Valley Drift where the remains of the elephant have been discovered.

That portion of the sketch (marked A) is occupied by the Coal Measures, which rise in hills two or three thousand feet in height, and present rounded outlines. The superficial soil is a clayey loam, resulting from the decomposition of the subjacent shales and sandstones, with no admixture of boulders or granite pebbles.

Skirting the flanks, and forming a well-defined terrace, sixty feet above the level of the Muskingum, is found the Valley Drift. It constitutes, for the most part, the rim of the valley, but in a few places the river has swept it away, and now impinges on the sandstones and shales of the coal-measures. The Drift reposes immediately on the subjacent rocks, which had been previously eroded, leaving an irregular surface. Its maximum thickness is sixty-three feet.

The intervening space, provincially termed "Bottom lands," consists of fine sands and clay, with an entire absence of loose blocks, boulders, or pebbles, and attains a maximum thickness of forty feet. This interval exhibits two well-defined terraces and a slight ridge, in the nature of an ôsar, which are not represented on the preceding sketch.

The following section was made across the valley, along the line *d e*.




A. Coal Measures.
B. Valley Drift.
C. Alluvium.

On the east side of the river, the rubble B is seen reposing on the flanks of the hills, while the immediate bank consists of loam C. The west bank rises abruptly from the water's edge to the height of ten feet.

succeeded by a bench about four rods in width, when there occurs a terrace about five feet in height. Another bench of about the same width then intervenes, with a terrace nine feet in height, and next a bench one-fourth of a mile in width, bounded by an oval ridge, beyond which the gravel terrace rises to the height of about twenty-six feet, capped with a layer of clay.

Proceeding north, along the left bank of the river, this terrace is soon lost sight of, and the subsequent formation (C) approaches the base of Putnam Hill.

Having rounded the point, the ancient terrace reappears in the valley of the Pataskala, forming an elevated plateau, much prized for building sites. Crossing the Pataskala, sharp and well defined, it is seen skirting the valley of the Muskingum for a mile and a half, and removed from one fourth to one half of a mile from its channel, until it intersects the rocks of the coal measures. It rises to the height of twenty-five or thirty feet above the bottom land, and then stretches back in a beautiful plateau.

Crossing to the Zanesville side, at the point E, it is seen along the flanks of the hills; but, a short distance above, the river intersects the coal-bearing rocks. At Slago's Run, the coarse gravel, cemented into a conglomerate by calcareous matter, is seen reposing upon the limestone; then succeeds an interval of nearly half a mile, over which it is obscurely traced; but above the town, at Cox's paper-mill, it reappears on the river bank in the form of a bluff sixty-three feet in height, and continues for three fourths of a mile, when it gradually recedes from the bank and assumes the form of a terrace. It is here that the observer has the best opportunity of studying its structure. Layers of fine sand alternate with layers of coarse pebbles, often intermixed with minute particles of vegetable matter. The materials are most thoroughly assorted, — a process which must have resulted from their prolonged suspension in the water. The beds of sand are freed from all aluminous matter, and often contain small pebbles of the size of a bullet, arranged along the lines of bedding. They exhibit many of the most beautiful examples of cross-stratification, which would seem to indicate that the materials were pushed along the bottom of an estuary and deposited amid shifting eddies. From the character of some of these beds, it is evident that the current by which they were deposited did not flow in the direction of the present stream.

The coarser materials consist of pebbles, rounded and smoothed, and derived from sources far remote; intermingled with angular and slightly rounded blocks from the immediate neighborhood. Among the former I recognized granite, sienite, quartz, hornblende, greenstone, yellow jasper, and black chert, together with pebbles of limestone, mainly from the Niagara group. It is not unusual to find in these loose deposits well preserved specimens of the Niagara corals, affording, in this respect, a very remarkable analogy to those of the Lake Superior region.

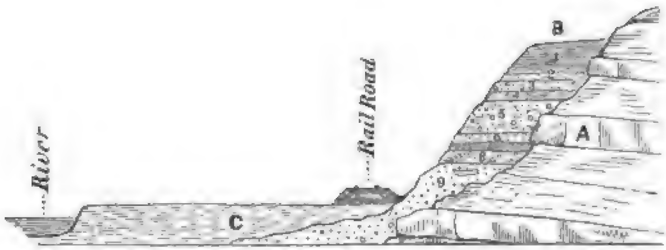
It was in this vicinity, at the point *c*, where Malinda street intersects the river, that the remains of the elephant were first discovered, about eight years since. A fragment of a tusk three feet in length was washed from the bank, and is now in the possession of Mr. James L. Cox, of Zanesville. Subsequently another was exhumed at the point *b*, near Mill Run. In December, 1852, Mr. Thomas S. Sedgwick, one of the engineers on the Central road, and Mr. Albert Spaulding, observed a portion of an incisor protruding from the bank at the point *a*, about eight feet above the railroad embankment. They soon succeeded in laying bare the two incisors, the four molars, and other fragments of the skeleton. Having heard that I was in the vicinity and was soon expected there, they suspended further operations in order to enable me to witness the exhumation, and critically examine the nature of the surrounding materials; a favor for which I desire to express publicly my sincere thanks. After my arrival, the excavations were resumed and revealed a portion of the cranium, one of the patellæ, one of the vertebræ, a rib, &c. Although, I doubt not, other portions of the skeleton might have been found, yet these bones were in so frail a state as to render them almost worthless, and, therefore, the farther prosecution of the work was abandoned.

The molars were in a high degree of preservation, and now constitute a part of the collection of the late Dr. J. C. Warren, of Boston.

The height of the elephant bed is: —

| | Feet. |
|---|---|
| Above the river at the Upper bridge at Zanesville | 37 |
| Above Lake Erie | 142 |
| Above tide water | 707 |

SECTION OF THE ELEPHANT BED.




A. Coal Measures.
B. Drift Terrace.
C. Alluvium.

| | Feet. | Inches |
|---|---|---|
| 1. Yellow loam, stratified . . . . . . . . . . | 8 | |
| 2. Fine sand, " . . . . . . . . . . . | 1 | |
| 3. Fine gravel, " . . . . . . . . . . . | | 6 |
| 4. Yellow loam, " . . . . . . . . . . . | 2 | |
| 5. Pebbles of igneous rocks, some of which are 4 inches in diameter | 6 | |
| 6. Yellow sand, stratified . . . . . . . . . . | | 6 |
| 7. Yellow loam . . . . . . . . . . . . . | | 7 |
| 8. Pebbles like bed No. 5, intermingled with large angular and slightly rounded blocks from the vicinage. Among these I observed a sandstone block, 5 feet × $1\frac{1}{2}$ × $1\frac{1}{2}$ : — another much rounded $2\frac{1}{3}$ × $1\frac{1}{2}$ feet : — a slab of limestone 2 × $1\frac{1}{2}$ × $\frac{1}{3}$ feet : also angular blocks of chert, containing 5 or 6 cubic feet. I have observed in this connection granite boulders, containing 8 or 10 cubic feet . | 2 | 6 |
| 9. Fine yellow sand, diagonally stratified with bands of fine pebbles, inclosing the remains of the elephant. . . . . . . . | 8 | 6 |
| Total . . . . . . | 29 | 7 |

The subjacent deposits at this point are concealed by the alluvium; but farther down the stream the same alternation of coarse and fine materials is found to continue to the water's edge. Their entire thickness, as before remarked, is sixty-three feet.

The bones do not appear to have been worn or broken, previous to their deposition; and from the fact that all of the molars, and both incisors, together with the cranium, were found together, I am inclined to the opinion that the entire carcass was floated into this ancient estu-

ary, and held together by the skin and strong integuments until the more perishable materials decayed.

There is another circumstance worthy of consideration, and that is, the occurrence of large fragments of rock immediately above these remains, which we have not seen repeated elsewhere in the section. This would seem to indicate the existence of a current of unusual turbulence, or that there was a renewal of the same causes by which the boulders were transported, after the interment of the carcass.

There are two other points within the Muskingum Valley where these remains have been found. Mr. A. C. Ross has a small molar, in a high state of preservation, which was found near the mouth of Salt Creek, nine miles below Zanesville. It had been washed from the adjoining bank, but it was not traced to its source. At Beverly, forty miles below Zanesville, three molars were taken from the Valley Drift.

Let us now examine the order of events which has happened here. That order, if I rightly interpret the phenomena, was as follows: First, the valley was scooped out of the Coal Measures, which form the great framework of this region; next, it was filled from side to side, to the height of sixty feet, with sand and pebbles, and occasional boulders,—all derived from regions far remote,—and angular blocks from the vicinity, at a time when the country stood at a lower level than at present. Then the country was elevated, during which the valley was partly reëxcavated, leaving behind the drift terraces as a record of the event. Again it sunk, when the comminuted sand and clay, forming the river bottom, was deposited, and rose again at successive intervals, leaving behind no less than three sets of alluvial terraces. After the formation of the most ancient, or drift terraces, the waters ceased to transport pebbles and angular blocks. The river now winds its way through this alluvial bottom, which was formed under different physical conditions from those which now prevail; that is, when the waters were higher, or, what amounts to the same thing, when the country was lower. There is nothing to induce us to believe that these changes have taken place within the human epoch. The latest of the terraces, we may presume, are older than man; but when compared with the first formed, which contain the remains of the elephant, they are comparatively modern.

In estimating the antiquity of these deposits, we should also bear in

mind that the highest drift, and that farthest removed, is the oldest. As the country was first depressed, and then rose by repeated oscillations, it follows that the higher portions, and those the most remote from the sources of this agency, would be first exempt from its ravages. We are here near its southern confines (latitude 40° N.), and in a region where it has penetrated only through the deeper valleys; and as these deposits are situated nearly 150 feet above Lake Erie, we must assign to them a higher antiquity than the uppermost of those which occur at lower levels.

### *Jackson County, Ohio.*

In the year 1838, Mr. Briggs and myself, then employed in the geological survey of Ohio, exhumed a portion of the skeleton of the fossil elephant from the banks of one of the tributaries of Salt Creek. The fragments consisted of two molars, several ribs, portions of the cranium, one incisor, two patellæ and several vertebræ.

These remains were found in an ancient lacustrine deposit, covered over with fine detrital materials, to the depth of eighteen feet, of which the following is a section:—

| | Feet. | Inches. |
|---|---|---|
| 1. Yellow clay or loam | 5 | 6 |
| 2. Yellow sand | 7 | 6 |
| 3. Irregular layers of sand shaded red and yellow, and firmly cemented with iron | | 8 |
| 4. Blue clay, inclosing the remains of the elephant, together with fragments of plants not identified | 5 | |
| Total | 19 | 8 |

This deposit forms a bluff on one side of the stream, while on the other occurs the more recent alluvium.

The following were the dimensions of the incisor:—

| | Feet. | Inches. |
|---|---|---|
| Length on the outer curve | 10 | 9 |
| Length on the inner curve | 8 | 9 |
| Circumference at the base | 1 | 9 |
| " two feet from base | 1 | 10 |
| " four " " " | 1 | 11 |

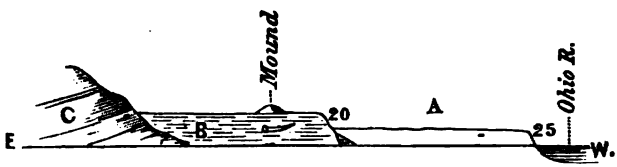
Its weight was 180 pounds; it was in a very frail condition and has since crumbled to pieces.

*Western Virginia.*

Mr. Alfred Sears, lately an engineer on the Baltimore and Ohio Railroad, has deposited in the museum of the Smithsonian Institution a few fragments of the skeleton of the fossil elephant, and from him I derive the following account of their geological position: —

"Above Wheeling the river bottom is very narrow; but as we descend the Ohio, it widens gradually, rising with one step until we reach a point four and a half miles from Wheeling Creek, when another step begins and continues beyond the place where these relics were found. The bottom is very level, and consists of a deposit of gravel and sand. At a point intermediate between Wheeling and the place where the cross-section occurs, other bones of the elephant were found in the 'Upper bottom,' twelve or thirteen feet below the surface."

The following is a cross-section of the Ohio valley near Wheeling: —




A. Bottom land.
B. Terrace in which the bones occur, 17 feet below the surface.
C. Coal-measures, rising in hills to the height of 200 feet.
Height of the steps is 20 — 25 feet.

With regard to the pebbles, Mr. Sears remarks that he has never seen in this part of the Ohio any of granitic origin, but they are for the most part of sandstone and limestone, the debris of the neighboring formation. Between these deposits and those of the Muskingum Valley, there is a coincidence in this respect, — that the elephant remains occur in the upper or oldest terrace; and to show that they possess a higher antiquity than the works of man, I would state that upon this upper terrace, and within a few feet, in a linear direction from the lower deposit of fossil bones, there is an aboriginal mound, thus proving that the topographical features of this vicinity must have been the same as we now behold at the time of the building of this structure.

*Kentucky.*

Hitherto the Big Bone Lick,* in Kentucky, has proved the great charnel-house of the remains of the mastodon and elephant. This locality has often been described as a swamp, with a substratum of blue mud, in which these colossal pachyderms, together with the bison and deer, belonging to existing species, were mired. This view, however, is erroneous. The deposits are very similar to those in Jackson county, Ohio, hitherto described,—consisting, first, of a yellow clay, fifteen or twenty feet in thickness, with a dark-colored clay below, containing the pachyderm remains. At the place where most of the excavations have been made, the yellow clay has been denuded, leaving the blue clay on the surface; and although in this swamp the bones of the deer and the buffalo have been found side by side with those of the mastodon and the elephant, yet they belong to two distinct geological epochs. The latter were entombed before the deposition of the yellow clay, and the former after its denudation. It is an undeniable fact that the pachyderm remains have been found, on penetrating

* The occurrence of these remains at this point was mentioned by Dr. Longeuil, a French voyageur, as early as 1744.

In the Journal of Christopher Gist, an agent sent out by the Ohio Company, occurs this notice:—

"Wednesday, March 13, 1751. We set out S. 45 West down the river Ohio. I met two men belonging to Robert Smith, at whose house I lodged on this side of the Mineami (Miami), and one Hugh Crawford. The said Robert Smith had given me an order on these two men for two of the teeth of a large beast, which they were bringing from towards the Falls of the Ohio (Louisville), one of which I bought and delivered to the Ohio Company. Robert Smith informed me that about seven years ago (1744), these teeth and the bones of these large beasts, one of which was somewhat smaller than the other two, were found in a salt lick, or spring, upon a small creek which runs into the south side of the Ohio, about fifteen miles below the Great Mineami River, and mostly above the Falls of the Ohio. He assured me that the rib bones of the largest of these beasts were eleven feet long, and the skull bones six feet across the forehead, and the other bones in proportion; and that there were several teeth there, some of which he called horns (incisors), and said they were upwards of five feet long, and as much as a man well could carry; that he had hid one in a branch at some distance from the place, lest the French Indians should carry it away. The tooth which I brought in for the Ohio Company was a jaw tooth of better than fourteen pounds weight. It appeared to be the first tooth in the jaw, and looked like fine ivory when the outside was scraped off."

through the yellow clay, in the blue clay beneath; but there is no evidence that the remains of the ruminants have been found under these conditions.

I cannot, therefore, subscribe to the opinion thrown out by Sir Charles Lyell, in his Travels in North America, that the matrix of these bones is the silt deposited by the recent action of the river; but regard it as part and parcel of the Drift clays so abundantly distributed over the West, which invariably preserve the same relation, the *blue* beneath, the *yellow* above. This knowledge of the order of superposition is understood by every inhabitant of that region, and is brought into requisition in every well that is sunk. Although in the nature of lacustrine deposits, I am disposed to refer their formation to a period when the continent was rising, and the superabundant waters were gathered into the depressions of the soil, forming lakes and pools.

## *Illinois.*

The profile of the prairies does not exhibit one uniform dead level; but a succession of elevations and depressions like the ground swell of the ocean transfixed. The culminating points attain an elevation of not over three hundred feet above Lake Michigan. The subjacent rocks are covered, for the most part, with transported materials to the depth, in some places, of two hundred feet. These consist of yellow clay and blue clay, the latter always subordinate; beds of sand and pebbles, rudely stratified, and boulders of granite, sometimes on the surface and at other times at considerable depths below.

To illustrate the character of these materials, I introduce two sections of borings made on the Chicago branch of the Illinois Central Railroad, in the spring of 1856.

SECTION AT RANTOUL.

| | | |
|---|---|---|
| 1. Prairie soil | 3 feet. | |
| 2. Yellow clay | 5 " | |
| 3. Gravelly yellow clay | 7 " | |
| 4. Blue clay | 51 " | |
| 5. Sand | 7 " | |
| 6. Boulder of syenite | 4 " | 6 inches. |
| 7. Quicksand | | |
| | 77 ft. | 6 in. |

SECTION AT URBANNA.

| | | |
|---|---|---|
| 1. | Prairie soil | 2 feet, 9 inches. |
| 2. | Yellow clay | 3 " |
| 3. | Red sand | 2 " |
| 4. | Yellow clay | 30 " 5 " |
| 5. | Sand with pebbles | 5 " |
| | | 43 ft. 2 in. |

Those mounds, like accumulations of Drift materials, devoid of stratification, so characteristic of New England, are here entirely wanting.

According to Dr. Stevens, in an excavation along the line of the Illinois Central Railroad, near Beaucoup, at the depth of about eighteen feet, the workmen found the remains of a mastodon in the prairie drift, below the yellow clay, in the older or reddish clay.

At Sandoval, about twenty-four miles north on the same route, other remains were found about twelve feet below, in a similar position.

At Bloomfield, Edgar county, the remains of a jaw and three teeth were found in the yellow clay, about three feet below the surface.

Near Danville, in the bluff forming the table-land of the country, the following section was observed.

| | | |
|---|---|---|
| 1. | Soil | 5 feet. |
| 2. | Gravel with bones of a pachyderm | 8 " |
| 3. | Clay | 2 " |
| 4. | Fine washed sand, reposing on rocks of the Coal measures | 2 " |
| | | 17 ft. |

## *Canada.*

The remains of the fossil elephant have thus far been found in only one instance in the Provinces, and that was at Burlington Heights, near the head of Lake Ontario. I am indebted to Mr. McQueen for the following account of the conditions under which they were found, communicated by Mr. E. Billings, of Bytown: —

" Burlington Heights is a narrow peninsula, about three fourths of a mile in length, and not more than half a furlong in width, which divides Burlington bay and the Desjardines marshes; an area of several thousand acres lying between the head of the bay and the town of Dundas, four miles distant. The marsh is still partially covered

with water; and recent experiments have shown that the bottom is a soft, floating mud, extending to a depth of eighty feet. Its present surface is scarcely above the waters of the bay. A sluggish stream from the high lands crawls down its centre, and in a deep, narrow glen, winds round the head of the peninsula into the bay, and now forms the Desjardines canal. I have no doubt that the large mass of alluvial matter has been formed by the stream in its untiring perseverance. The peninsula is one hundred and ten feet in height. The land on each side of the amphitheatre in which the marsh is inclosed rises to a great height, say one hundred and fifty feet above the level of the peninsula. The great puzzle to me is the cemented gravel; it begins at the surface, is thirty feet thick, is regularly bedded, like the strata in a limestone quarry, has a considerable dip, or inclination, and is all but impenetrable. It is as difficult to drill or blast as any limestone. The sand on which it is incumbent is too clean and too fine for building purposes; of this quality it continues for perhaps thirty feet downwards, and then turns into a loose, coarse gravel, like the beach of the lake. The bones were deposited in the fine sand, in which there is not a vestige of a shell of any description."

These cemented materials, overlying the elephant bed, having the consistency of a rock and dipping at a considerable angle lakeward, are seen on the right bank of the ravine along the Great Western Railway, several miles distant from Dundas; — thus showing that they maintain their persistency over a considerable area, and that their accumulation is due to causes which have ceased to operate.

As to the character of the fossil bones, the reader is referred to the letter of Mr. Cottle, in the Annals of Natural History, and copied in the American Journal of Science, Vol. XV. p. 282.

### *New England.*

Hitherto the remains of the fossil elephant have been found *only* in Vermont. In the construction of the Rutland and Burlington Railroad the partial fragments of a skeleton were found at Mount Holly, *on the* very summit of the line, 1,440 feet above tide water, and 1,350 feet above Lake Champlain.* There are here the remains of a small peat

* Agassiz, Proceedings Am. Ass. 1849.

swamp; but Dr. Warren informed me during his lifetime that Mr. Henshaw, who was mainly instrumental in bringing these relics before the world, was strongly under the impression that some of the bones were taken from below a very large boulder.

There is here a deep cut through the unstratified drifts, and the surrounding hills, which attain a much higher elevation, are strewn with large boulders.

*New York and New Jersey.*

In New York and in New Jersey, the remains of the mastodon have been found in a high degree of preservation in beds of shell marl, on which is imposed a deposit of peat. The shells are, in all instances, of fresh water origin, and belong to existing species; but, thus far, no fragments of a skeleton of the fossil elephant have been found in this connection.* In the valley of the Ohio, however, the remains of these two classes of pachyderms have been found side by side, thus leaving no doubt that they were contemporaneous. The remains of the elephant at the West certainly occur in the drift materials which occupy the valleys, while those of the mastodon are found in what often appear to be erosions in the old drift.

The presence of the remains of fresh water shells of existing species ought not, however, to be relied upon as a proof of the extreme modern origin of these deposits, since it is an undoubted fact that, in Europe and in South America, where river and land shells occur associated with fossil mammalia, even of the Newer Pliocine period, they are found to belong to existing species. Thus at Brentford, on the Thames, the elephant remains are associated with fresh water shells of existing species. So, too, in the ossiferous caves of Brazil, the remains of extinct mammalia, like the megatherium, are associated with existing species of land shells. It, therefore, admits of no doubt that a race of mammalia has sprung into existence, flourished, and become extinct, while the land and fresh water shells have remained unchanged.†

* For detailed information with respect to these deposits, the reader is referred to Dr. Warren's Memoir, "The Mastodon Giganteus."

† Wood on the Upper Tertiaries, Geol. Soc. 1849. Lyell's Elements, *passim*.

### *The Southern States.*

In the region of the South, along the borders of the Atlantic and the Gulf of Mexico, there is a series of superficial deposits embracing the Lower, Middle, and Upper Tertiaries; and in the Mississippi Valley, Sir Charles Lyell has detected a deposit which he regards as the equivalent of the Löess, in which are found the remains of the mastodon.

There is, also, along the borders of the Gulf of Mexico, a wide belt of sandy materials, apparently more recent than the Newest Tertiary, which, although characterized by an entire absence of boulders, may be really contemporary with the Drift.

According to the testimony of Southern observers, to these pachyderm remains must be assigned as high an antiquity as the Newer Tertiary.

### *North Carolina.*

From the banks of the Neuse River, Mr. T. A. Conrad, many years ago, obtained the bones of the mastodon, the elephant, the hippopotamus, the horse, the deer, and the elk, all belonging to extinct species, in a bed equivalent to the Upper Tertiary, covered over by a deposit of marine shells, in places fifteen feet thick, which belong to the Pleistocine period. The bones were very much water-worn, so that in many instances the characteristic differences of the animals to which they belonged could not be recognized. In conversing with him on the subject, he assured me, in the strongest terms, that these remains, as thus disclosed, belong to the Upper Tertiary; and their rolled appearance would seem to indicate that they might have been washed from a bed of greater antiquity than that in which they were deposited.

### *South Carolina.*

Mr. Tuomey, in his Geology of South Carolina, regards the mastodon as characteristic of the Upper Tertiary; and states that forty-six per cent. of the associated marine shells are found to be extinct. In a private note, he remarks: "It is very difficult to arrive at correct conclusions as to the precise position of these remains where you do not find them yourself. I am, however, satisfied that both the mastodon and the mammoth lived at the period of the deposition of what we call in Virginia the Miocene."

In a subsequent note he embodies the following information: —

"Fragments of a tusk of one of these animals have been found in a cave in North Alabama, together with bones of the megalonyx, as determined by Dr. Leidy.

"I have a tooth of the mammoth, said to be from the Miocene of Maryland. It was found by a highly intelligent gentleman, whilst engaged in marling operations, and transmitted to Edward Ruffin, Esq. of Virginia. An account of its discovery will be found in the *Farmer's Register.* I have also a tooth and portion of a tusk of a mastodon found in the same formation in Virginia. Aside from the testimony of the respectable gentleman to whom I am indebted for these specimens, the marl attached to them, as well as their color, left no doubt in my mind as to the deposit in which they were found.

"I placed in the cabinet of the South Carolina College a fine tooth of a mastodon found under similar circumstances, in Darlington District, South Carolina. Other specimens were found overlying the Eocene, near the Santee Canal, but these, I believe, are not supposed to be derived from that formation.

"At several localities in Alabama, remains of the mastodon occur in superficial deposits."

### *California.*

The remains of the fossil eléphant have been found in numerous instances in this region, and under circumstances which leave no doubt as to their true geological position, that is, in the gold-producing drifts; — the same association having been observed by Sir Roderick Murchison, in Siberia.

Mr. Smith, connected with one of the Pacific Explorations, showed me a tooth of the fossil elephant, supposed to have been derived from one of the lignite beds of Oregon.

### *Foreign Localities.*

The pachyderm remains found in the Pampas of South America, according to M. D'Orbignay, occupy a position intermediate between the Tertiary and Diluvial formations, which he designates Pampéen.

In Europe, the *Elephas primigenius* had a wide geographical range. Its remains have been found from the Arctic Sea to the Mediterranean. It there originated early in the Newer Pliocine, and survived through

the whole of the Glacial epoch, and perhaps even until after the period of the Terraces; for its remains are found, for example, in the cliffs of Norfolk, England, beneath the drift, in the Löess of Northern Germany, and in the ice cliffs near the mouth of the Lena, where they must have been encased at a time when that portion of the continent had assumed nearly its present level.

There are two localities in the British Isles, where the bones of the elephant have been found entombed in fluviatile or lacustrine deposits, supposed to be above the Drift. "It is not difficult to conceive," remarks De la Béche (Geological Observer), "that these mammals may have revisited the British Isles, again connected with the mainland, (supposing that the area had been submerged and again elevated), so that their remains may be found in lacustrine and fluviatile deposits, above the marine accumulations formed during the interval of depression. . . . Assuming only one submergence sufficient to disconnect the British Isles, followed by an elevation sufficient to restore the connection, it would be inferred that lacustrine and fluviatile accumulations would be the highest amid which we should expect to discover the remains of the *Elephas primigenius* and his contemporary mammals."

It has hitherto been asserted by almost every osteologist that the elephant of this country was identical with that of Europe. This, however, as will be shown in a subsequent part of this article, is a matter of exceeding doubt. If, however, this should be found true, and if the prevailing notions as to the simultaneous origin of species in different parts of the earth be correct, we are authorized in the inference, that the elephant appeared as early, and survived as long on this continent as on the eastern, and that the causes, whatever they may have been, which led to his extinction, were not local but general in their operation.

In bulk the American elephant far surpassed the existing species, and was adapted to a wide geographical range. Contemporary with him was the mastodon (*M. giganteus*), of a more ponderous frame, but of an inferior size. The fossil beaver (*Castoroides ohioensis*), tenanted the streams and lakes. Herds of cattle (*Bos bombifrons* and *Bison latifrons, L.*), roamed over the plains, while the tapir wallowed in the swamps. In the milder regions of the south, visited by the elephant and the mastodon in their migrations, lived the great

leaf-eating megatherium, the mylodon, the megalonyx, the hippopotamus, the horse, the elk, and the deer, all belonging to extinct species; while at the head of the carnivora stood the colossal lion (*Felis atrox*, L.), which then, as now, was monarch of the forest.

The observations made in the Southern States would seem to indicate that the elephant originated during the Newer Pliocene period; but my own observations lead me to infer that he commenced his existence before the drift agencies had entirely ceased; when the waters stood at a higher level, when the contours of the continent were different, when a different climate prevailed, and when a subarctic vegetation stretched far towards the tropics; at a time when the valleys had been excavated by the retiring waters, and the streams had assumed nearly their present direction. It was a period of erosion, which ought to be marked by distinct geological monuments. I would designate it as the FLUVIATILE PERIOD.

Although, in rare instances, the remains of the elephant and the mastodon have been found side by side, there are deposits, in which elephant remains are entombed, apparently older than any that contain those of the mastodon; and at the same time, there are deposits apparently newer, which contain the mastodon, in which those of the elephant have never been found. The inference therefore might be drawn, that, although at one time contemporary, the one was introduced earlier, while the other survived later.

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## 2. NOTE ON THE TEETH OF AN ELEPHANT DISCOVERED NEAR ZANESVILLE, OHIO. By Professor J. WYMAN, of Cambridge.

THOSE who have studied the remains of the American mastodon and elephant, must have been struck with the fact, that while the bones of the former, and even many entire skeletons, have been brought to light, in a state of nearly complete preservation, those of the latter have nearly all decayed, so that no considerable portion, such as a limb, or even an entire cranium has as yet been described. We know the existence of the American elephant at present almost entirely by the

teeth and trunk alone, and these have been thus far so imperfectly described that the modifications which they undergo in the dental series remain to be determined.

The four remarkably well preserved molars of the American elephant or mammoth, which have been referred to me by Mr. Foster, are important additions to the discovered remains of these animals. They were found together, in apposition, with some fragments of a cranium, under such circumstances as to leave no doubt that they all belonged to one and the same individual. Some fragments of tusks, but no other teeth, were seen with them. Their great size, and the number of laminæ, indicate that they were ultimate or sixth molars, so that the last members of the dental series had been brought into use. A complete series of ultimate molars, from the same individual, has not been hitherto described; usually only single ones having been found at a time. A conception of the great size of the Zanesville specimens may be formed from the fact that the aggregate weight of the jaw, in a dried state, was fifty-four pounds.

The following are the dimensions of the right and left upper molars: —

| | Right. Inches. | Left. Inches. |
|---|---|---|
| Greatest length | $13\frac{1}{4}$ | $13\frac{1}{2}$ |
| Greatest height, when resting on the grinding surface | $10\frac{1}{2}$ | 11 |
| Length of grinding surface | $8\frac{3}{4}$ | 9 |
| Breadth of " " | $4\frac{1}{4}$ | $4\frac{1}{4}$ |
| Whole number of laminæ | 29 | 30 |
| Laminæ of grinding surface | 18 | 18 |

The weight of the right tooth was fifteen pounds, and that of the left, seventeen pounds and eight ounces.

The whole number of laminæ was probably larger originally, as there are indications that some of them have been ground out; still they are more numerous than in any described tooth. The largest number hitherto described is twenty-six.*

The lower molars are longer and not so high as the upper; the grinding surface is concave instead of convex as above. It seems probable from the conditions of the teeth, that a portion of the anterior extremity had been worn off, and that the number of plates may have been originally greater.

* Owen. British Fossil Mammalia and Birds, p. 225.

| | Right. Inches. | Left. Inches. |
|---|---|---|
| Whole length | 14½ | 15 |
| Length of grinding surface | 9 | 8¾ |
| Breadth of " " | 3¾ | 3½ |
| Whole number of laminæ | 24 | 25 |
| Laminæ of grinding surface | 17 | 17 |

The weight of each lower molar was eleven pounds. Professor Owen has described a specimen,* larger than either of these, it having been sixteen inches long, and provided with twenty-eight plates.

The tusks I have had no opportunity of examining. They were seen by Mr. Foster, who found the longest fragment about eight feet long. The extremity was gone, but from the form and proportions of the part examined, Mr. Foster estimated the entire length to be about twelve feet. The tusks were much less covered than in *E. primigenius.*

*Is the mammoth of America specifically distinct from that of the Old World?* Owen regards them as identical. Dekay believes the American mammoth to be a distinct species, on the ground, that in a tooth examined by him, the number of laminæ was greater than in the elephant of Europe or Siberia. Thus far observations are not sufficiently extensive to determine this question. The character derived from the number of laminæ is not exact, since the range of variation is very great, and the larger the tooth, the greater the range. A correct conclusion can be reached only by examining a large number of corresponding teeth in the mammoths of the Old World and the New. It is very probable that the entire cranium, when it is discovered, will serve to settle this question. Among the Siberia fossils described by Falconer and Coutley, the crania of the different species of elephant were highly characteristic, each species having its own peculiarities strikingly marked and well défined. The theory of the identity of the species of mammoths of the Old World and the New is afforded by the analogies of the geological distribution of other Pachyderms. If the theory be correct, then we have one and the same species extending through fifty degrees of latitude, and more than two hundred and eighty degrees of longitude; in fact through the whole habitable portion of the northern hemisphere above the twentieth parallel. The

* Owen. British Fossil Mammalia and Birds, p. 225.

mastodons of America are different from those of Europe; and those from South America are different from those of North America. The sevree, the tapirs, the rhinoceros, the bison, the ox, and the lion, found fossil on this continent are specifically distinct from any of the species found in the eastern hemisphere. The elephant of Africa constitutes a species distinct from that of Asia, and the Sivalic fauna shows the coexistence of many species in one and the same geographical region even. But there are no facts which go to show that any of the species of pachyderms have so wide a distribution as that assumed for the *E. primigenius*, when it is asserted that it is common to the two hemispheres. Under the circumstances, before asserting either the specific identity or the difference of the remains in question, it is better to wait for further developments, which will, in time, no doubt, furnish the necessary evidence.

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### 3. On a Batrachian Reptile from the Coal Formation. By Professor Jeffries Wyman, of Cambridge.

The remains described in this connection, were recently discovered in the coal-fields of Ohio, by Dr. J. S. Newberry. Those which were most complete consisted of a nearly entire skeleton of a salamandroid animal, imbedded in the matrix, and seen from below, about five inches in length, exclusive of the tail, which had been broken off. The vertebral column between the proboscis and the head, consisted of between twenty and thirty pieces, which were quite small, and without any indications of having transverse processes which characterize batrachians, or of ribs. The head was broader and much more expanded transversely than in salamandroids or tathyoids, and more closely resembled the cranium of frogs. As in these last, the pterygoids were slender near the median line, but broad externally, the orbits large, and the angles of the jaws projected backwards beyond the occiput. The head is nearly as broad as long, and the jaws are quite regularly arched. A few simple pointed teeth were visible in the intermaxillaries, but there were no indications that there existed any pieces interposed between the lower jaws at the symphysis, as is the case in frogs and toads. The bones of the limbs correspond with those of urodels,

the humerus and femur being hollow at the ends, and the bones of the forearm remaining separate and movable on each other, instead of being consolidated as in Anourous Batrachians. The number of toes appeared to be five for each foot, though there was some uncertainty in regard to those of the fore foot.

Slight traces of a scapular order were visible, but too indistinct to indicate the anatomical structure.

If it should prove true that these animals had five toes before as well as behind, the foot-prints from the coal, which have been described as having the same number, would meet with a satisfactory explanation. No living Batrachian has more than four toes before.

The indications in this country, of the existence of reptiles during the coal period, which have been already described, are the *Cheirotheran* foot-prints discovered by Dr. King; those of the *Sauropus*, by Mr. Lea, and others discovered by Professor H. D. Rogers. In addition to these, may be enumerated the bones of the *Dendrerpeton* obtained from the cavity of a coal tree, by Sir Charles Lyell and Professor Dawson; and the *Baphetes* discovered by Mr. Dawson, and described by Professor Owen.

A portion of the remains of another skeleton was also discovered, consisting of thirteen vertebræ, with the corresponding pieces of ribs, all of which were of the same size and development, as is the case with those from serpent-like animals. The vertebræ were nearly destitute of spinous processes, but the articulating processes were broad and expanded, and in this respect bearing some resemblance to those of menopoma. The vertebral ends of the ribs were not bifurcotal as in salamanders, nor broad and expanded, as in some tathyoids. No transverse processes were visible on the vertebræ. The ribs were flattened, of nearly equal breadth throughout, distinctly grooved on the side, and strongly curved. In these respects they differ very materially from any known Batrachians, and more clearly resemble the serpents, or serpent-like lizards. The animal may have been a true Batrachian with ophidian characters superadded, just as Lepidosteus is a true fish, with certain reptilian features developed.

The remains of the two animals just described are of great interest, since they form important additions to the scanty evidence already existing of the creation of air-breathing animals as far back as the coal period.

## 4. Remarks on a Specimen of Fossil Wood from the Devonian Rocks, (*Gaspé Sandstones*) of Gaspe, Canada East. By J. W. Dawson, Principal of the McGill College, Montreal.

This specimen was discovered by Sir W. E. Logan, in 1844, in the sandstones and shales near Brachaut Bay, described in his Report of progress for that year, and containing carbonized comminuted plants, and other imperfect vegetable remains. These beds were ascertained by Sir William to underlie unconformably the lowest carboniferous rocks, and to form a portion of the Devonian System.

The trunk was originally about four feet in length, and several large fragments of it have been placed by Sir William in the collection of the Canadian Survey. The largest and best preserved of these fragments is seven inches in length, and nine and one half inches in its greatest diameter. It is perfectly silicified, with the exception of a thin coating of smooth coal, perhaps representing the bark. The color is black, and the texture very compact, with the exception of a tendency to split into concentric layers, the surfaces of which are thinly varnished with carbonaceous matter. These layers are shown by microscopic examination to be rings of annual growth. The thicker end of the fossil has, like the circumference, a smooth carbonaceous coating in part, giving it the appearance of having been the base of the stem. This may, however, be accidental, more especially as other surfaces, evidently not external, have thin coaly films, perhaps resulting from bituminous infiltration.

The *cross section* exhibits a well preserved and uniform cellular tissue. The cells are almost perfectly circular, not crowded, and imbedded in a semi-transparent silicious paste without structure. The limits of the rings of growth are well defined, being marked by cells of smaller diameter and more irregularly distributed than the others. The medullary rays are indicated by a few radiating cracks filled with silicious matter without structure, and by a slight tendency to a radiating arrangement of the cells. The growth rings, where best preserved, are about a line in average breadth. (Figs. 1, 2, 3).

*Fossil Wood from Devonian System, Gaspé, Canada East.*

Fig. 1.

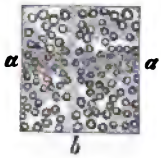


Fig. 2.

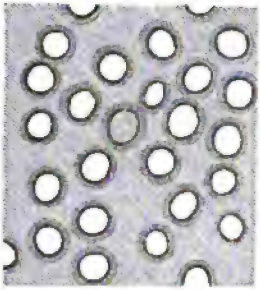

Fig. 3.

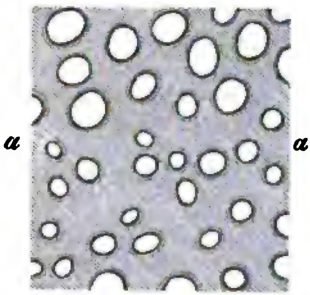


Fig. 4.

1. Transverse slice, 60 diameters, (*a*) growth line, (*b*) medullary ray.
2. " " 300 " in middle of growth ring.
3. " " 300 " (*a*) outer margin of growth ring.
4. Longitudinal section in direction of medullary rays.

In the *longitudinal section*, parallel to the medullary rays, the cells are seen to be much elongated and to terminate in conical points. Under a high power, they show traces of transverse and diagonal fibres, sometimes decussating. No medullary rays nor disc structures are visible. (Fig. 4.)

At first sight the transverse section resembles the outer cellular cylinder of Lepidodendron, or of some Lycopodia; but the apparent uniformity of the tissue throughout the trunk, the rings of annual growth, and the character of the longitudinal section, point to the conifers.

The absence of disc structure from a tissue so well preserved, weighs against this; but Professor Gray has observed* that, in the American Yew, where there are few discs, delicate spiral markings like those in the present fossil appear in their place. The young wood of some recent conifers, as, for example the Chili Pine, gives in the cross section a tissue approaching in the roundness and separation of the cell-openings to the present specimen. The fragment of fossil wood from the Devonian Rocks of Cromarty, figured by Miller, does not very closely resemble that from Gaspé; but it has been too much compressed to admit of satisfactory comparison.

On the whole, it seems probable that this ancient tree was a conifer or closely allied to the conifers; though in so far as my knowledge and means of reference extend, it differs materially from any previously observed form.

Note. — Since this paper was read, I have observed in Murchison's Siluria, page 358, a quotation from a letter of Professor Unger, referring to fossil plants from the Devonian "cypridina schists" of Saalfield, in Meiningen. Among these are some which seem to be primitive forms of cycads and conifers, possessing characters of which, says the Professor, no one has yet had any idea; and some present such a singular organization that he terms them the "prototypes of the Gymnosperms." It is quite probable that among the plants thus characterized there may be forms similar to the Gaspé fossil.

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## 5. Observations on the genus Archimedes, or Fenestella, with Descriptions of Species, etc. By Professor James Hall, of Albany.

The term "Archimedes" has long been in use among American geologists; and is the generic name given by Le Sueur to a Bryozoan composed of broad, reticulate expansions, which are spirally arranged around an elongated axis, or stem. The axis is solid, or irregularly cellular in its interior structure; the expanded portions have the general character of *Fenestella* upon the lower or external side, while the upper

* Botanical Text-Book, fourth edition, page 46.

and inner side is in like manner celluliferous. The cellules are cylindrical, with circular or sub-circular mouths, arranged along the branches in two or more rows; branches rounded or angular above, connected by transverse processes, leaving oval or sub-quadrangular interstices.

In all the essential characters, the foliate expansions of *Archimedes* corresponds to *Fenestella*, according to the extended description of this genus by Mr. Lonsdale; and in detached fragments cannot be distinguished generically from other forms of the same genus. Some of the species have more than a double row of cells on the branches, and correspond to the genus *Polypora* of McCoy, but, nevertheless, that character is found in true Fenestella, according to the description above cited.

The mode of growth, therefore, constitutes the only reliable character for separating *Archimedes* from *Fenestella;* and should this character be hereafter considered of sufficient importance, I propose to retain Le Sueur's original name "ARCHIMEDES."

Dr. D. D. Owen has several times alluded to the "*Archimedes*" in his various Reports; and in a paper published in the American Journal of Science and Arts, vol. 43, p. 19, he gives a figure of one of the species as the "Archimedes of Le Sueur," but suggests that "it may be only a new species of Retchporea."

This figure of Dr. Owen is of a large species; but being merely the spiral axis, furnishes no characters for specific identification. It retains the thickened base of the foliate expansion, and where this is broken through presents the irregularly cellular structure, common to the axis of all the species. This structural character, or the remains of fenestrules on the edges of the spire, as seen in Dr. Owen's figure, have been mistaken by M. D'Orbigny for the animal cells; and upon this character he proposes a new genus "*Archimedipora*," having the cells arranged upon the salient angles of the spiral band, and places the fossil in the Devonian System. No such fossil is known to occur in the Devonian System in this country. His description is, "cellules longues, placées aux saillant d'une spirale, autour d'une tige allongée." It is quite unnecessary to say that the Archimedes of the carboniferous limestones exhibit no characters corresponding to this description; and the paleontologists of our country who are disposed to adopt the name of "*Archimedipora*" will do well to compare the generic characters given by M. D'Orbigny with the fossil itself.

Below are given some of the characters of a few species known to me at the present time. These are given here for the purpose of calling the attention of geologists and collectors to these fossils, with a hope that they may prove useful in the identification of strata, and that materials may be obtained for a more complete illustration of this peculiar group of *Fenestellidæ.*

Fenestella (*Archimedes*) Owenana. Axis slender, the spire rapidly ascending; branches rounded and sub-angular on the celluliferous side; cells in two rows, one on each side of the branches; connecting processes slender, and rather distant.

In the Keokuk limestone, Keokuk, Iowa, and at Appanoose, Illinois.

Fenestella (*Archimedes*) Wortheni. Axis strong, robust, having a little more than three turns of the spiral to an inch, where the axis is one fourth inch in diameter; expanded portion with small oval fenestrules, and strong, closely arranged connecting processes. Branches rounded on the celluliferous side, with a faint, sharp, meandering ridge down the middle, which is sometimes thickened; rows of cells two or more. Cells sometimes occur on the connecting processes.

In the Warsaw limestone, Warsaw, Illinois.

Fenestella (*Archimedes*) Swallovana. Axis slender, finely striated; spiral rapidly ascending, about six turns in an inch, where the axis is one eighth inch in diameter; branches comparatively strong, rounded below, sub-angular above; connecting processes slender; cells in two rows near the base, — outer ones unknown.

In the limestones of Kaskaskia and Chester, Illinois, and Crittenden county, Kentucky.

Fenestella (*Archimedes*) Meekana. Axis slender, dextral, rapidly ascending; making five revolutions of the spiral in an inch, where the diameter is one sixteenth of an inch; fenestrules oval or oblong; cells in two rows, there being two on each side of the branch in the space of each fenestrule, and rarely another at the junction of the connecting process with the branch.

This species is much more slender than either of the preceding, and is readily distinguished by the rapidly ascending spire.

In the Kaskaskia limestone, Chester, Illinois.

Fenestella (*Archimedes*) laxa. Axis very slender, sinistral, rapidly ascending, making one revolution in an inch; fenestrules oblong-

oval or subquadrangular; cells in two rows, closely arranged; apertures elevated; axis and exterior of branches finely striated.

In the Kaskaskia limestone, Chester, Illinois.

There are other species, of which I have fragments too imperfect for a satisfactory determination. The direction of the spiral axis may be either dextral or sinestral, in different species, and we have evidence that this character differs in the same species, and in the same individual.

There are, likewise, other forms of Fenestella in the Kaskaskia limestone, in which the reticulate expansion is arranged between the branches of a strong stem, which bifurcates from the base: and others in which this thickened portion, corresponding to the axis of those above described, occurs only on one side. Were the axis, or strong support, to give the character, these species would constitute a group equally distinct, as ARCHIMEDES, from the usual forms of FENESTELLA, and which might be designated under the name of LYROPORA, possessing the following characters.

Bryozoum consisting of foliate reticulated expansions, margined on either side by strong stony supports which diverge from the base, curving outwards and upwards. The foliate expansion is spread out between these diverging arms, which are themselves formed by the coalescing and thickening of the branches.

The growth of these stony supports is sometimes direct, or in a line parallel with the point of attachment; and in other species there is first a receding of the whole from that point, an extreme thickening of the support on one side, and a gradual narrowing to the opposite margin where the branches originate.*

FENESTELLA (*Lyropora*) LYRA. Bryozoum composed of strong, solid, or stony support which bifurcates from a slender base, and, curving at first abruptly outward and upwards, continues gradually diverging above; the space between the two branches occupied by a reticulate expansion, consisting of strong diverging branches and more slender connecting processes, leaving small oval or round-oval interstices; surfaces of branches rounded, marked by four or five rows of cells.

* These bifurcating processes, with the point of attachment, resemble the lower jaw of the common frog, and are known along the Mississippi valley as the "Frog-mouth coral."

In the Kaskaskia limestone, Chester and Kaskaskia, Illinois.

FENESTELLA (*Lyropora*) QUINCUNCIALIS. Base strong, broadly rounded, point of attachment obtuse; fenestrules on the non-poriferous side nearly round, on the poriferous side subquadrangular; branches slender, divergent, and bifurcating, on the celluliferous side rounded, with an irregular double row of cellules, and sometimes only a simple row on the centre of the branch.

The cellules are usually arranged one on each side of the branch in the middle of the fenestrule, and one on each side at the junction of the connecting process, which are more conspicuous than the others; thus giving one more conspicuous cellule in each angle of the fenestrule. This arrangement, and the oblique direction of the branches, give a beautiful quincunx arrangement to both cellules and fenestrules.

FENESTELLA (*Lyropora*) SUBQUADRANS. Bryozoum, with the lateral supports nearly direct from the base, diverging at an angle of more than 80°; foliate expansion extending beyond the lateral processes; branches somewhat strong and rounded on the non-poriferous side; connecting processes short; branches on the poriferous side flattened, with the pores somewhat irregularly distributed in four rows; fenestrules on the non-poriferous side somewhat oblong-oval, or subquadrangular; fenestrules on the poriferous side oval, smaller than on the non-poriferous side.

In the Kaskaskia limestone, Chester, Illinois.

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## 6. ON THE RELATIONS OF THE FOSSIL FISHES OF THE SANDSTONE OF CONNECTICUT, AND OTHER ATLANTIC STATES, TO THE LIASSIC AND JURASSIC PERIODS. By W. C. REDFIELD, of New York.

IN the publications of Professor W. B. Rogers, and Mr. E. Hitchcock, Jr., on the red sandstone formations of Connecticut, New Jersey, and other States, founded on some of their contained fossils, a higher geological position than that of the new red sandstone has been as-

signed by these writers.* Without questioning their conclusions, I would state that we consider the fossil fishes of these rocks as the most characteristic and reliable fossils for determining the age of the formation. The determinative value of these fossils is perhaps enhanced, also, by the small vertical range to which some of the species, and at least one of the genera, are probably limited. But these fishes, although numerous, as well as characteristic, do not appear to have been referred to, in any manner, by the above-named writers.

Attention is invited, therefore, to a descriptive account of one genus or group of these fishes, which was read to the New York Lyceum of Natural History, in December, 1836, by Mr. John H. Redfield, and is found in Vol. IV. of the Annals of that Society. It was founded

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* Professor W. B. Rogers, on the age of the coal rocks of Eastern Virginia. *Am. Jour. of Science*, Vol. XLIII. p. 175, (1842). Also, in Proceedings of the Boston Society of Natural History, Vol. V. p. 14, (1854), *E. Hitchcock, Jr., M. D., in Am. Jour. of Science*, Vol. XX. (N. S.), p. 22, (1855).

Professor Rogers first assigns to the coal rocks of Eastern Virginia a position near the bottom of the oolite formation of Europe, while from some fossils "discovered in a particular division of the new red sandstone of Virginia," he expects to be able confidently to announce the "existence of beds corresponding to the *Keuper* in Europe;" doubtless in the extensions of the New Jersey Sandstones or *Newark Group*. I propose the latter designation as a convenient name for these rocks, and those of the Connecticut Valley, with which they are thoroughly identified by footprints and other fossils, and I would include also, the contemporaneous sandstones of Virginia and North Carolina.

At a later period, (1854,) Professor Rogers recognizes the general equivalency of the Eastern and Middle Belts of Virginia, and the Eastern or Deep River Coal Belt of North Carolina, all of which, in his view, ought to be placed in the Jurassic series, not far probably above its base. In relation to the more western belt, the occurrence of *Posidoniæ* and *Cypridæ*, in Pennsylvania, with sauroid coprolites and imperfect impressions of leaves of Zamites, he considers as sufficient to identify, as one formation, the disconnected tracts of this belt in North Carolina and Virginia, and the prolonged area of the so-called New Red Sandstone of Maryland, Pennsylvania, and New Jersey; and that they are of Jurassic date, but little anterior to the coal rocks of Eastern Virginia.

Professor H. D. Rogers (1839) proposed the name of *Middle Secondary* to this group (for convenience' sake), to distinguish it from the Appalachian formations on the one hand, and from the green sand deposits on the other. — *Third Report on Geology of Pennsylvania*, p. 12.

Mr. Hitchcock describes a new species of *Clathopteris* discovered in the sandstone of the Connecticut Valley. This fossil fern, found near the middle of the series in Massachusetts, he refers to the Liassic period.

upon a careful comparison of the genus *Catopterus* with the fossil fishes of different formations in Europe, as these are portrayed in the great work of Professor Agassiz, then recently received. Such portions of the description and observations then made as relate directly to the geological age of the formation will now be quoted.

Of the genus *Catopterus*, species *C. gracilis*, he says: "Tail forked, equilobed; scales extending a little upon the base of the upper lobe." And in regard to the equilobed tail, he adds, in a subjoined note: "This indeed is not *strictly* the case. Its structure, however, is analogous to that of the *Semionotus*, ranked by Agassiz among the *Homocerci*, and differs most decidedly from that of the true *Heterocerci*, where the scales, and probably the vertebræ, extend to the extreme point of the upper lobe." He adds:—

"In the arrangement of Agassiz, this fish would be comprehended in the order *Ganoides*, and family *Lepidoides*. Its equilobed tail would assign it to the second division of the family, the *Homocerci*, as he has termed them. From seven fusiform genera now arranged in this division, it is entirely excluded by the posterior position of its dorsal. It may therefore be ranked between the genera *Semionotus* and *Pholidophorus*, being analogous to both in the structure of the tail, and in its serrated fins, and to the latter, in the articulation of the rays. From the situation of the dorsal fin, I have thought the name *Catopterus* to be applicable to this new genus."—*Annals Lyc. Nat. Hist.* Vol. IV. pp. 38 and 39.

Nearly twenty years have elapsed since the promulgation of these careful and apparently conclusive observations, which do not appear to have been weakened or set aside by any subsequent researches. It is proper to state that the two analogous genera above mentioned, are found in the oolitic series as well as in the lias, and it is believed that few or none of the kindred genera have a lower range.* The above

* A single case of semi-heterocercal structure as occurring in the coal rocks of Autun in France, was mentioned to us by Professor Agassiz, in 1846. As we learn nothing more of its appearance in the palæozoic series, may there not possibly be an error as regards the authenticity or position of this fish? If otherwise, it does not seem to have appeared again until after the Permian period. On the other hand, it appears to be admitted that the true heterocerques, of the Palæoniscus type, do not appear above the Trias, and I think they are not found above the Permian.

It should be noted that Sir P. Egerton has described a most singular fish from

observations afford at least sufficient warrant for the cautious, and perhaps too limited inferences with which Mr. Redfield's paper in the Annals is concluded, namely: —

"It has of late years been generally admitted that the sandstone from which these fishes are derived is of much later date than the old red sandstone, to which it was once referred, and these remains confirm this belief. The *Palæonisci* of Europe (true heterocerques), have never been found below the coal-measures, while they extend upward to the copper slate of the *Zechstein* or magnesian limestone. In the case before us, we find a species of *Palæoniscus* (Ischypterus) accompanied by a fish, the structure of whose tail approaches that of the *Pholidophorus*, and of other fishes never found below the lias. This fact would seem to imply for this formation, even a higher situation in the series than that which is now assigned it by geologists." — *Annals, etc.* p. 40.

The American Association of Geologists and Naturalists at the meeting held in Albany, in April, 1843, requested Mr. John H. Redfield to prepare a report on the fossil fishes of the United States. His report was presented to the Association at New Haven in May, 1845. It was withheld from publication by its author on account of the expected visit of Professor Agassiz to this country, and with a view of commending the whole subject to his examination. In the review of the fishes of our new red sandstone, so called, the report stated as follows: —

"NEW RED SANDSTONE. — Under this term I include the extensive sandstone formation of the Connecticut River Valley; the small and isolated basin on the Pomperaug River, near Southbury, Conn.; the New Jersey sandstone, extending from the border of the Hudson River south-westerly, to the interior of Virginia; and, also, the formation known as the Coal Rocks of Eastern Virginia." — *Report*, p. 4.

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the upper strata of the new red, of a genus hitherto unknown, which has but little irregularity in the structure of its caudal base. This fish, the *Dipteronotus cyphus*, *Eg.* is very short and broad, with a double dorsal, and is altogether so *unique* in its character, that its occurrence may be deemed to affect but little the chronologic inferences which are drawn from the varied structure of the numerous genera and species of the Lepidoid family. — See *Geological Journal*, 1854, p. 369: *With a figure.* — W. C. R.

"All the fishes hitherto found in these rocks belong to the order *Ganoidæ*, and to the family *Lepidoidæ*." —*Report*, p. 5.

"Professor Agassiz has made two subdivisions in this, as in other families of the order *Ganoidæ*, founded on differences in the structure of the tail. In the first of these, (*Heterocerci*,) the upper lobe of the tail is vertebrated, and is usually longer than the lower, and the scales of the body extend upon the upper lobe nearly or quite to its extremity. The other division, the *homocerci*, have the tail regular, either forked or rounded, and the scales do not extend upon the upper lobe; though in some genera they are slightly prolonged in that direction. The fishes of our sandstone formations above mentioned would seem to belong to the first of these divisions, or those with heterocercal tails. They do not, however, exhibit this structure in the same degree which obtains in the fishes of the older European rocks, or even in those of the new red sandstone or magnesian limestone of England and Germany. The only two genera which have yet been found in our rocks differ somewhat from each other also in the degree of heterocercal structure which they present; those species which, following Professor Agassiz, in *P. fultus*, I have allotted to the genus *Palæoniscus*, having the heterocercal structure more decided. But even in these, the tail has a different aspect from the *Palæonisci* of Europe. In the latter, the upper lobe of the tail seems hardly to partake of the character of a fin, and the lower lobe appears to be only a finlike appendage of the upper, like a second anal fin, while the scales, and no doubt the vertebræ, extend to the extreme point of the upper lobe."

"The other genus, the *Catopterus* of our rocks, exhibits the heterocercal structure in a still more modified degree. So nearly does it approach in this respect some genera classed as homocercal fishes, such as *Semionotus* and *Pholidophorus*, that in an early memoir published in the Annals of the Lyceum of Natural History, Vol. VI., I was led to rank it in that division, subject to a qualifying note. Its relations are, however, rather to the heterocercal fishes, or, perhaps, to an intermediate group.

"This point is an important one in its bearing upon geological questions, for it is now well ascertained that the true heterocercal tail [in the Lepidoids] is peculiar to the palæozoic, and lower mesozoic rocks, no fish of that character having been found higher in the series than the triassic rocks, while the true [strict] homocercal tail does not occur

below the lias. When, therefore, we find in the fishes of our sandstone rocks, a structure which seems to be intermediate between the true homocercal and the heterocercal divisions of Agassiz, the conclusion seems irresistible, that the including rock *cannot be older* than the triassic, while it must be placed *at least as low* in the series as the lias or oolite."—*Report*, pp. 5, 6.

"Only four species of the genus *Catopterus* are yet known; three of which are found in the red sandstone of New England and New Jersey, and the fourth in the coal rocks of Eastern Virginia."*—*Report*, p. 7.

His descriptions of these four species of Catopterus are found in the Report, and were then prior to any known notice or description of these fishes, other than our own. These descriptions, together with those of the more numerous species of the genus *Ischypterus*, are yet withheld from publication, on account of the contemplated arrangements for completing a monograph of the fishes of this formation in the United States.

I have thus shown the examinations and conclusions of Mr. J. H. Redfield on these fishes, as first published in 1837, and as found in his Report to the American Association, in 1845. In the first of these, he points out the age of the containing rocks, and within the same limits that now appear to result from all the subsequent researches.

At the meeting of this Association held in Cincinnati, in April, 1851, the present writer made a communication on the Post-Permian character of the Red Sandstone rocks of Connecticut and New Jersey, as shown by various fossils. I then exhibited, together with two species of *Voltzia*, some specimens of the genus Catopterus from these rocks, showing the homology of their caudal structure with that of the *Catopterus macrurus* from the coal rocks of Eastern Virginia. This was induced in part by the fact that Sir Philip Egerton, in a paper of Sir Charles Lyell, in the third volume of the Journal of the Geological Society, had separated this Virginia species from its congeners in the New Jersey and Connecticut rocks, on the ground that the former belonged to the homocercal, and the latter to the heterocercal divisions of Professor Agassiz.†

* Others have since been obtained.

† Sir Charles Lyell *On the Structure and Probable Age of the Coal-Fields of the James River, near Richmond, Virginia.* Journal of the Geological Society, Vol. III, 1847, from pages 275 to 278.

Previous, however, to this publication of Sir Charles, repeated and careful examinations, with Professor Agassiz, of the numerous species of Catopterus in my possession, collected from the localities of the three different States, had appeared to establish fully their similarity, in respect to the caudal structure. Also, that the *Catopteri* of all the localities, including Virginia, might continue to be referred to the *homocerci*, as in the case of some European genera, or that, more properly both they and the other fishes of these rocks, might be referred to a distinct and intermediate division, which is *sub*-heterocercal in its character, if I may so speak. I, therefore, reclaim the *Dictyopyge* of Sir Philip Egerton, founded on my species, *C. macrurus*, as still belonging to the genus *Catopterus*. I refer to this matter on the present occasion on account of the important relation which it has to the geological age of these fishes, as found in the several States.

I may add in further explanation, that Sir Charles Lyell, in the paper referred to, states that "the genus Catopterus was instituted by Mr. Redfield for certain species of heterocercal fish from the Connecticut red sandstone." He seems not to have noticed that the genus was instituted by Mr. J. H. Redfield, in 1836, for a *homocercal* fish, according to the analogies afforded in the *Poissons Fossiles* of Agassiz; and he probably alluded only to my own later notices in Silliman's Journal, 1841, Vol. XLI. p. 27. All the fishes obtained by him from the sandstone of the Connecticut River are also pronounced heterocercal, while the Virginia fish is stated to be homocercal; and this is supported by the opinions of Professor Agassiz, as given on first seeing specimens of these fishes in Europe. Based on this designation, Sir Philip Egerton proposed his new genus *Dictyopyge* for the *C. macrurus* of the Virginia rocks.

In regard to the other fishes of New England and New Jersey, Mr. J. H. R. had reluctantly followed the work of Professor Agassiz in assigning them to the genus *Palæoniscus*, although this eminent naturalist had then only seen two imperfect specimens; but Mr. R. then alluded to their structural affinity with the liassic fishes, as we have seen in his concluding paragraph already quoted, and impliedly in the descriptive portion of his paper. In my own notices, of 1841, referred to above, I suggested that their less heterocercal form, and the peculiar structure of their fins warrant their being placed in a separate genus. Sir Philip Egerton recognizes the division, as did Professor

Agassiz in 1846, and Sir Philip proposes for the new genus the name *Ischypterus.*

The question to which of the divisions of Agassiz, the Catopterus of Connecticut, and this fish of Virginia belong, is simply one of degree. Even if we were to admit a slight difference in this case, it could hardly imply the wide separation which has been claimed. Such a marked division founded on the structure of the tail cannot depend on the use of a term, however authorized, and must be decided by the fishes themselves.

In regard to this point of distinction, may I not quote the matured views of Sir Philip Egerton, so well expressed in the Journal of the Geological Society, 1854, p. 368: "Although this character, derived from the organization of the caudal fin, is one of great value and significance in the determination of various genera of fossil fishes; it is, nevertheless, necessary, in drawing general conclusions, to be careful not to assign to it more importance than it is strictly entitled to; for we find, by the comparison of several genera, that it is not one of those well-defined trenchant characters which can be affirmed to exist or not, as the case may be, but that it is variable in amount, passing from extreme *heterocercy* to absolute *homocercy* by a sliding-scale so gradual, that it is (at all events in fossil examples) most difficult to define a positive line of demarcation between the two forms."

As the terms have hitherto been used, such line of demarcation, if it exist, appears best indicated at the division between the palæozoic and the mesozoic strata; and perhaps in lesser degree, at the close of the triassic period.

In all our *Catopteri* the scales of the caudal base terminate near the middle rays of the upper lobe, "and not on the upper margin as in a true heterocerque tail."* Good figures by Dinkel of the species *C. macrurus* of Virginia are given in the above-mentioned paper of Sir Charles Lyell.

It has been seen that Mr. J. H. Redfield considers the other fishes of the Connecticut River and New Jersey rocks as more heterocercal in degree than the Catopterus. In some of the species, however, this difference seems less obvious after a close examination of the structure, than it appears at first view. One or two of the species in my possession, I think, are even more nearly homocercal than the Virginia fish.

* See Egerton as last quoted, page 370.

I desire to add, that two of the *Lepidoti* from the table-land of India, of which figures are given in the Journal of the Geological Society, show very strong resemblances to two or three of my fishes from the sandstone of Connecticut River at Sunderland, to one of which I had proposed the name *Ischypterus Marshii*. Is it not probable that the vast extent of sandstone and trap in that distant region is of like age with our Newark group?

Already I have ventured to state verbally to the Association, that in the valuable collection of fossils from the coal-field of Deep River, in North Carolina, now exhibited by Professor Emmons, I have recognized several well-characterized fragments of the genus Catopterus. A close comparison of these with specimens in my cabinet may, perhaps, show a difference of species. But my present impression is that of identity with one of the New Jersey species.

It would be premature to conjecture how far the new fossils of Professor Emmons may affect the question of the relative age of these rocks. But when we consider that these fishes evidently belong to fresh-water or estuary deposits, as is shown by the entire absence of any remains of large marine fishes, by an almost equal absence of shells, and by the numerous fossilized fragments of terrestrial vegetation with which the fishes are associated, the chronological evidence afforded by their characteristic organization would seem to be more determinate than that of saurians, plants, or marine fishes, whose general habitat and power of distribution enable them to occupy a greater range in the geological series.

P. S. It is proper to add, that having now compared the remains of Catopterus of Professor Emmons' collection with my own specimens of the genus, I find them scarcely distinguishable from most of those of the New Jersey and Connecticut rocks. Indeed, they appear to be identical with *C. gracilis*. The chief differences appear in the larger size of most of the Carolina specimens, which may be due to conditions more favorable to their growth, and in the less flattened condition of the basal portion of the strong and elongate front ray of the pectoral fin, — owing, probably, to a nearly equal pressure on all sides in the carbonaceous paste or sediment in which they were fossilized.

New York, September 12, 1856.

7. On the Occurrence of Fish Remains in the Carboniferous Limestone of Illinois. By A. H. Worthen, of Warsaw, Illinois.

The occurrence, in a fossil state, of the remains of fishes in the mountain limestones of the Western States, has, up to the present time, been regarded as extremely rare, and, if we except the thin bands of limestone about to be described, these remains are among the rarest organic forms that meet the eye of the collector in his researches among the several beds that compose the sub-carboniferous or mountain limestone series of the region under consideration.

Several years since, while engaged in collecting the fossils of this formation in the vicinity of Warsaw, Ill., a thin band of gray crinoidal limestone was observed, which contained the palatial bones of fish in considerable abundance, and subsequent research has revealed two more of these "*platforms of death*," lower down in the series, densely filled with these remains. The subjoined section gives the relative thickness and succession of the series in this vicinity, and also shows the position of the fish beds.

The upper fish bed is situated in the upper part of what I shall call, for the want of a better name, the Lower Archimides Limestone, inasmuch as it is the lowest bed at present known to contain fossil corals of the genus Archimedes.* The remains from this bed, with one or two exceptions, consist entirely of palate teeth associated with Cyathophylla-formed corals, Spirifer Oralis, and Spirifer Cuspidatus. The middle fish bed is situated at the base of this Archimedes limestone, and near its junction, with the cherty beds below. This bed has proved by far the most prolific in these remains, and from it I have obtained more than five hundred well preserved teeth at a single locality and on a surface not exceeding ten feet square. The fossils from this bed are mostly jaw teeth with comparatively few palate teeth and spines.

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* A peculiar form of Fenestella. See a description of species in this volume.

The matrix in which they are imbedded is a coarsely granular crinoidal limestone not exceeding four inches in thickness, and sometimes so friable as to be easily crumbled between the fingers. This character of the matrix enables the collector to obtain these delicate and beautiful fossils in a rare state of preservation. In addition to the Cyathophylla-formed corals mentioned above, as occurring in the upper bed, we have in this an interesting coralline form, occurring in equal abundance and belonging to a genus with which I am unacquainted. I have also obtained the head of one species of Actinocrinus from this strata. This bed is separated from the one above by the limestones and marlites of the Keokuk quarries, from twenty-five to thirty feet in thickness.

The lower fish bed is situated near the top of the Burlington crinoidal limestone, and the strata in which the fish remains occur do not differ materially, either in their lithological or paleontological character, from the associated strata. This crinoidal limestone forms the base of the mountain limestone series in this region, and rests directly upon rocks equivalent to the Portage and Chemung groups of New York.

This lower bed has yielded a great number of teeth, though they are usually of smaller size than in the upper beds. This stratum was first observed at Quincy, Ill., and subsequently has been recognized in Henderson county, in the same State, and at Augusta, in Iowa, points nearly one hundred miles distant from the one first named, showing, as I think, that these fish beds are not local, but retain their peculiar fossiliferous character over a considerable geographical extent of territory. In addition to the fine teeth and spines which have been obtained from this bed, it has also afforded one well-marked bone nearly four inches long.

From the specimens before us, it would seem that the fishes of the sub-carboniferous era increased in size from the commencement to the end of that period, and that by far the greater portion of them were cartilaginous, only two well-marked bones having been obtained among at least one thousand well-preserved teeth.

The Pentremital and Archimedes limestones of southern Illinois, which form so striking a feature in the geology of that region, and which properly overlie those in this section, wedging out in a north-

erly direction, and entirely disappearing before reaching the mouth of the Illinois River, have afforded us several very fine specimens of fish remains; but a very careful examination has not yet revealed any strata in which they occur in such profusion as in the lower beds.

In the more southern extension of this formation, through Tennessee and North Alabama, notwithstanding the greatly increased thickness of these beds, attaining, as they do, in the valley of the Tennessee River, a maximum of more than one thousand feet, these remains are exceedingly rare, and a careful research of several days during the past winter yielded only three or four specimens of this class of fossils.

An interesting inquiry suggests itself as to the causes which led to the destruction of such great numbers of the vertebrated inhabitants of the ocean during the deposit of the thin bands of limestone in which their remains are entombed in such profusion. Unlike the ichthyolites of the old red sandstone below, and the lias and chalk above, those of the mountain limestone now before us, only occur in the fragmentary condition of isolated teeth and spines, affording in themselves no clue to the causes which may have operated in their destruction, and leaving us to conjecture whether they fell victims to the ravages of disease, or were destroyed by the sudden injection of heated water or noxious gases into the ocean which they inhabited.

For the want of the necessary authorities on this branch of paleontology, and having had no opportunity of comparing our specimens with those already described from European localities, we have not attempted to determine how many of our fossils can be identified with European species. Nevertheless, we may reasonably expect, that when our collections from the mountain limestone and coal-measures of the Mississippi Valley come to be fully collated and determined, many new species will be added to those already known to occur in the upper paleozoic series.

*Section of the Sub-Carboniferous or Mountain Limestone Series exposed in the River Bluffs in Adams and Hancock Counties, Illinois, showing the position of the Fish Beds.*

| | Thickness. | |
|---|---|---|
| | | Coal Measures. |
| | 25 feet. | Concretionary and Brecciated Limestone. |
| | 30 feet. | Arenaceous Limestones and Marly Clays with Archimedes. |
| | 10 feet. | Magnesian bed. |
| | 45 feet. | Geode bed. |
| Upper Fish beds. | 40 feet. | Lower Archimedes Limestone. |
| Middle Fish beds. | 70 feet. | Cherty beds. |
| Lower Fish beds. | 100 feet. | Quincy and Burlington. Crinoidal Limestone. |

# III. ZOÖLOGY.

## 1. On the Names of Animals and Plants, with Reference to the Origin of Languages, and to the Countries where Nations passed their Childhood. By Dr. David F. Weinland, of Cambridge, Mass.

Every European naturalist, who comes to North America, must be struck with the fact, that the Anglo Saxon race, which has had possession of this continent for three centuries, has not formed *new* names for the *new* animals and plants of the country; but — with the exception of some artificial and some Indian names — has applied and still uses throughout, old English names for the American animals, though the latter are nearly all quite different from those animals to which the names originally belonged. Such names are, for instance, Bear, Badger, Catamount, Mole, Deer, Chamois, Buffalo, Rabbit, Porcupine, Robin, Quail, Grouse, Cuckoo, Goatsucker, Jay, Shrike, Starling, Linnet, Goldfinch, Wren, Sparrow, Pigeon, Turtledove, Coot, Rail, Godwit, Bittern, Widgeon, Teal, Lizard, Adder, Toad, Treetoad, Salamander, Perch, Bass, Gurnard, Sculpin, Mackerel, Blenny, Barbel, Hake, Flounder, Sole, Eel, Lamprey, etc., all of which are applied in the American-English language, to animals specifically or even generally different from the European animals which they designate in England. Thus, for instance, Robin means in America, Turdus migratorias, a bird belonging to the thrush family, while in England it is used to designate Sylvia rubecula, which belongs to the warblers; the name Partridge means in England a bird belonging to the Perdicid, (Quails, etc.), in America a Tetraonoid.

Starting from this fact, we have been naturally led to consider the names of animals in other languages, and we have been surprised, that in all those to which we have referred which belong to the Teutonic, the Pelasgic, and Semitic stock, we find the same fact, namely, that every nation has, only for the animals and plants of its native country, real roots of words, which express one typical kind of animals or plants and nothing else; and that no nation has a peculiar true name for any

foreign animal or plant, but that it either applies to these names of its native animals, or it borrows the names from another nation; or uses comparing, artificial names, like Guinea-pig (German: Merschweinchen), Camelopard, Nile-horse (Greek: Hippopotamus, German: Nilpferd), Sea-horse (German: Walross), etc. How names are borrowed by different languages we see particularly in the most striking representatives of the animal kingdom. The name lion in German; löwe, leu, in Old German; lewo, in Anglo-Saxon, lio; leon, in Dutch; leeu, leeuw, in Swedish; leion, in Danish; loeve, in Icelandic; leo, lion, in Polish; lew, in Bohemian; leo, in Latin; in the Romanic languages, (French, Spanish, and Portuguese,) lion is a Greek root-word, λέων (leon). The Semitic languages have other roots for the same animal; in Hebrew arí means the male, labi the female, and gur the young. Now we know that the lion is a native of Greece; that it has lived within historic times in Macedonia, therefore, it has a true name in the Greek language; we know further, that it now lives all over that part of Asia and Africa which seems to be the cradle of the Semitic nations, namely, in Syria, Arabia, and Egypt, therefore the Semitic nations have another true name for it; and, further, they have three such names for the different sexes and ages; we know, too, that the lion never lived in Central, or Northern, or Western Europe, therefore neither the Teutonic nor Sclavonic languages have true names of their own for this typical animal; they have borrowed the name from the Greek, the nearest nation which had the lion native. The tiger, an animal as typical as the lion, has no original name in any European language, nor has it in the Hebrew, for the tiger is not (as stated in some dictionaries) from a Hebrew, but from a Persian root. Now this agrees again exactly with the geographical distribution of the animal. Though it lives all through the middle of Asia from Hindostan to Siberia; it does not live in Syria nor in Egypt, therefore it has no name in the Semitic language. Moreover, it does not occur in Europe, therefore it has no name in the Palasgic, or Teutonic, or Celtic. All these nations have borrowed the name from that Persian root. The elephant is another striking example. Its name is from either a southern or south-western Asiatic root, or it is borrowed from the Hebrew äleph, which means an ox. The elephant is an inhabitant of southern Asia, and if the name is really of Hebrew origin, it shows that the Hebrews compared it with their own, because the elephant never lived

in the native country of the Semitic nations, and they, therefore, have no true name for it. Another example is the name camel. This has a Semitic root, in Hebrew it is Gämäl. The animal is a native of the Semitic country, and, therefore, it has there a true name, while all European languages have borrowed the name from the Semitic, because the camel never lived wild in Europe. In order to be rightly understood we must notice here a mistake, which we see sometimes made by philologists. The fact that the name of an animal or a plant is common to two or three or more different languages, is often used to prove that those languages have some affinity to each other. The names elephant, tiger, and camel, are common to the Palasgic, Teutonic, and Celtic languages. Does that show any affinity between these languages? To us it shows nothing else than that all these different nations have taken the name with the thing from that nation which first had it. If, as has been stated, the name cow is common to the languages of all those nations which have cows, this shows to us not an affinity of the languages, but only that the cow lived wild in the native country of one single nation, and that hence it has been carried to other nations, and its name with it. But sometimes nations really seem to make new names for foreign animals, either because they do not know the names used in the country where the animal originates, or because, perhaps, that name has too strange a sound. But what are the names thus made! They never are true new names, they are mostly artificial, comparing names, such as Nile-horse, or hippopotamus, for that heavy pachyderm of Africa, which has hardly any resemblance to a horse, or Guinea-pig for that little knowing animal from Brazil, or camelopard, also, as the ancients called the Giraffe, comparing it to a camel and to a panther; or Sea-cat as the Germans call the long-tail monkeys, because they saw them coming over the sea, and compared them with cats; or earth-apples, as in some parts of Germany the potatoes are called, etc. These examples show how much nations strive to reduce the names of all foreign animals and plants to those of such as are native with them, and they often even go so far in this as to apply the names of their native animals and plants to foreign ones which are entirely different. This has been done to a great extent by the Anglo-Saxons, as they have come over from England to North America.*

* See the names mentioned above, robin, etc.

Now if this be true, if nations have only true names for the animals which inhabit their own country; moreover, if it be true, as all philologists believe, that a nation can originate root words only in its childhood, while forming its language, we can draw the important conclusion, that *wherever we find a nation which has true names for all the typical animals and plants of a certain country, that country is the seat of its childhood.*

Thus zoölogy and botany and philology combined, may help ethnography in determining the cradles of the nations of the earth. We purposely say the cradles, not the birthplaces, because our arguments do not reach farther back than to the childhood, that is, the time in which a nation forms its language by originating root words.

Now is this principle a practical help in our investigations? We have tried it with language with which we are best acquainted, the German, and have found the remarkable fact, that the high German language, which has a true name not only for all the typical mammalia, birds and reptiles, (but also for all the different fresh-water fishes of southern Germany,) has not any true name for the most characteristic mammalia, birds and fishes of those very seas which border upon lower Germany. All these animals have only comparing names, such as Seehund (sea-dog) for seal, Seeschwein (sea-hog) for dolphin, Seeigel (sea-urchin) for the echinus, Seestern (sea-star) for the star-fish, Seeteufel (sea-devil) for Lophius, Seenadel (sea-needle) for the Syngnathus or needle fish, etc. This fact seems to me to show, that the High German language is the language of a continental nation which lived its childhood in southern Germany. How far this is true for the Low German and the Anglo-Saxon, we are at a loss to say. They seem to have many true names for the sea animals, such as seal, and many others; but the question arises, then, whether they have not taken those names from a nation which lived upon those sea-shores before they came there. This question must arise because there are still so many typical sea animals for which they use only comparing names. But we have no doubt, that the Laplander has true names for all his sea animals.

We see from these considerations what value there would be in a critical catalogue of the names of animals and plants which would indicate exactly the kind of animals or plants meant by a given name, and also tell the geographical distribution of each. Such a dictionary

might also be of philological value in relation to the origin of many verbs. In running through a Hebrew dictionary for names of animals and plants, we found that the author (Simonis) tried to carry back every name to a verb; thus he derives anaphah, the heron, from anaph, to be in wrath; athon from athan, to walk away slowly; cariack, serpent, from carack, to fly away quickly; and in the same manner we find such names treated in dictionaries of other languages. Now we may justly ask;—Which is the more natural, that men, in the state of nature, first make verbs and then derive from them the names of the animals, or that they first name the animals which live around them, by a certain sound, and afterwards derive a verb from that sound, a verb which expresses very naturally the most striking character of that animal? We deem the latter process the more natural. Thus we might rather derive carack, "to fly quick away," from cariack, the serpent, than inversely. We have no doubt that, at least in Hebrew, many verbs are still to be recognized as derived from names of animals.

I have begun to collect materials for a catalogue of the names of animals and plants, as spoken of above; and I shall be glad to receive information and contributions from all those who are interested in the subject. When the work is published, the name of the contributor will be given as authority for the statement.

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## 2. On the Digestive Apparatus of the Acanthocephala. By Dr. David F. Weinland, of Cambridge, Mass.

The anatomy of a worm would seem perhaps to many, a matter of not very great importance. But those who have followed the development of science know that correct observations made upon the so-called lower animals, are often the starting points for the most beautiful generalizations, and afford the most simple, and therefore the broadest, basis for the physiological understanding of animal life. For in these lower animals, in a worm, for instance, we have all the physiological systems, the reproductory as well as the digestive and respiratory or-

gans in the simplest form, and we can see them all acting together in one field of the microscope.

Some years since a remarkable discovery (the penetration of the Spermatozoa into the egg), was made on an intestinal worm, and now this fact has become a law extending very likely throughout the animal kingdom. This, I think, is the true view of the so-called lower animals and of the study of their organization.

In spite of the labors of centuries, there still remains a large number of animals which are said to have no distinct digestive apparatus. And this is certainly true of the microscopic Rhizopodes, an order of Infusoria, which may rightly be called Protozoa, since we have not yet been able to bring them under the head of either of the four great branches of the animal kingdom. These Rhizopodes feed, as my friend Edward Claparède, of Berlin, discovered some years ago, by throwing all their body over their prey, (generally another Infusorium,) which then at once appears in the midst of the body of the Rhizopod and is some minutes after a shapeless ball of food. Now these Rhizopods really consist of nothing but a viscous mass of the most variable form, without a membrane around the body, but with a heart, if we may call such a roundish, reddish dot, pulsating at fixed intervals, from which the intestine fluid seems to start.

We see here the lowest form of animal life, and in looking at such a simple development of all the physiological organization, we are not at all astonished to find no distinct intestine. It is equally true that such an intestine does not exist among many of the Radiata, the Polypi, for instance; and now there are said to be even among Articulata, some animals which are destitute of a distinct digestive apparatus. Thus among Helminthes or intestinal worms, no mouth or intestine has yet been found, either in the group of Cestoda (tape-worms), or that of the Acanthocephala or Echinorhynchi. These worms are said to feed by imbibition through the skin. Of the Acanthocephala, a large species of which is very common in the intestine of the hog, Dujardin, in 1845, says: "Animaux sans bouche et sans tube digestive; se nourrissant par absorption."* *Blanchard*, in 1848, who succeeded in injecting the circulatory apparatus of many Helminthes, says of these

* See Histoire Naturelle des Helminthes, p. 483.

worms: "Point d' ouverture buccale, point de tube digestif."* *C. T. von Siebold*, in 1848, says: "Bei den Echinorhynchen wird höchst wahrscheinlich die Zufuhr von Nahrungsstoffen vermittelst der Einsaugungskraft der Hautbedeckung vermittelt."† *Diesing*, in his Systema Helminthum Vindobonæ, 1851, Vol. II. p. 18, says: "Os in proboscidis apice; Tractus intestinalis proprius nullus." Thus all these helminthologists agree in this, that there is in Acanthocephala no intestinal canal; though Diesing, in opposition to the others, speaks of a mouth on the top of the proboscis, which, however, as Siebold has already observed, and as we can fully confirm, is a mistake, there being but a pit in that place, and no opening at all.

I hope to throw in the following observations some light upon this subject, namely, to show that there exists in Acanthocephala a real nutritive system which takes up food from outside, consisting of two rather long stomachs hanging down from the head into the cavity of the body, starting from two mouth-openings near the basis of the so-called neck. I will add that I have succeeded in showing the existence of this digestive apparatus to Professor Louis Agassiz, in the living animal, to his full satisfaction.

Last winter, in studying the anatomy of the North American turtles for the first volume of the work of Prof. Agassiz, I had the rare chance of dissecting many fresh specimens of these reptiles. I directed my attention particularly also to their parasites, which until now have been but little studied. In the small intestine of Emysserrata, I met in all specimens I dissected (more than a dozen) a Nematoid, the Cucullanus microcephalus Rud, and an Acanthocephal, a new species of Echinorhynchus, both, but particularly the former, in large numbers. In this Echinorhynchus I not only recognized at the first sight the distinct stomachs, as described above, but also, at least in some specimens, the two mouth-openings. In all the specimens which I observed more closely, (about fifty,) the stomachs were filled with a brownish granular matter. The brown granules which they contain are irregular and float in a transparent fluid, and I sometimes succeeded in pressing this food out through a mouth-opening by a slight pressure of the covering-glass. But the structure of these stomachs is very curious; they are

* See Recherches sur l' Organisation des Vers, p. 283.

† See Lehrbuch der Vergleichenden Anatomie der Wirbellosen Thiere, p. 128.

not simple sacs, but contain, or rather are built up of a network of fine tubes, with a central tube in the midst, from which the finer ones start. Again, these finer tubes are connected in the neighborhood of the mouth-openings with the extensive vascular system of the walls of the body. On the transit between the tubes of the stomach and the vessels of the walls of the body, I saw a valve which opened periodically, and I watched once for a good while the process of floating from the tubes of the stomach into these vessels.

Thus we think the digestive process of Acanthocephala — for very likely the same is the case in the whole order — is this: The two mouth-openings receive the food and lead into the tubular system of the stomachs, which at the same time serve as digestive glands. We may compare them with the appendices pyloricæ of some fishes, the Salmonids, for instance. From these stomachs the digested food is led into the vascular system of the walls of the body.

The Echinorhynchus of Emys serrata, upon which these observations are made, when fresh and without exposure to water, and placed under the microscope, is very transparent. Still the mouth-openings are generally not to be distinguished, but whenever I saw them, they were wide open. They were still larger in another Echinorhynchus, which I met with in Lophius piscatorius.

Though from the statements of helminthologists, as quoted above, it might seem that they have not noticed this extensive apparatus; still this is by no means the case. On the contrary, the two stomachs were described long ago, and very accurately, particularly by Siebold, l. c. p. 134, under the old name of Lemnisci. Siebold describes them under the organs of circulation, because he unluckily did not see the two mouth-openings. But even these were seen by Mehlis, but as nobody until now has seen them since, their existence has been denied. The supposition of Blanchard, that the proboscis with its bag is at least in the younger state of the worm, a kind of intestine, the mouth-opening of which is soon obliterated, is evidently a mistake. The whole mechanism of the apparatus for stretching out the proboscis, which is exactly the same as in Cestoda, and which can be studied most beautifully in Tetrarhynchus, forbids this supposition.

But there might still be left some doubt at least about the name of this digestive apparatus, as we have described it above. There are, strangely enough, two mouth-openings; and the structure of the stom-

ach is very similar to that of a gland. But if we call digestive apparatus those organs which lead the food from outside into the animal through certain openings, and which digests that food and passes it over into the circulatory system, we are justified in calling so the above-described system of Echinorhynchus.

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## IV. PHILOLOGY AND ETHNOLOGY.

### 1. On the Relations between Chinese and the Indo-European Languages. By S. S. Haldeman, of Columbia, Pa.

§ 1. The form of Chinese is so different from that of Latin or Greek, that we might readily consider as fallacious all attempts to exhibit an identity of words between them.

§ 2. Some have endeavored to establish such an identity upon certain words of like form and meaning, which cannot be depended upon, being frequently the result of accident, like the English *bank* (of earth) and Mandingo *banko*, with the same meaning; the English *shave* when compared with the Eskimo *shavie*, a knife, and the Brazilian *ara* with "air," and *co* with "go." Similarly, the Kaffer *le*, *lo*, for "that," corresponds with Fr. le, Ital. lo; the Betjuana *ké* is near to the Germanic "*ik*" and Latin EGO; and the Bushman *ăe* to the English *I.*

§ 3. Resemblances like the following, between Chinese, English, etc., should be admitted with extreme caution, as likely to be accidental: gnaé, *to gnaw;* sëuk, SUGO, *to suck;* báy, *to buy;* wân, *white*; wan, *crooked* (wend, wind); tam, *damp;* tan, *a red color;* tàp, *to reiterate;* lók, *to leak;* t'hek, *a house* (TECTUM); lap, *loose skin;* t'hew, *a thread* (thew); t'hong, *a thread, a line* (thong); kap, *to collect together*, (keep, CAPIO); kap, *a cape;* kat, *to cut;* etc.

§ 4. From the paucity of Chinese words, many of them are overburdened with meanings, which gives room for accidental resemblances. Thus there are fifty different characters read "sun," and of some of these the meanings are very diverse, one meaning *believe* and *real*, another *thick* and *liberal;* but none of these meanings agrees with the English *sun* or *son.* Of twenty Chinese words, *sit* (meaning to eat, to

lose, to know, to rub, a rule, etc.), the nearest to English is that meaning a residence, often called a *seat*. This resembles the language of a child who would use essentially the same word for stick, cake, did, toad, dog, duck, scratch.

§ 5. From the monosyllabic nature of Chinese, and the necessity of placing a vowel between most consonants, the words are very different from those of Latin. Thus the word Batavia has been cut down to pa, and cap, *a ship*, stands for the Malay capal; Welsh ceubal, *a ferry-boat;* Gaelic cabaile, *a navy;* Gr. *ΚύμΒη*, *a boat*, *σ-ΚαΦος*, *a skiff;* Heb. Qă'B, *a concave vessel;* Arab. CūB, *a cup*, CaV*θ*al, *a ship*.

§ 6. We must, therefore, in comparing Latin with Chinese, reduce it to its roots, reject the prefixes con-, sub-, post-, ex-, cr-, str-, etc., before consonants, and reduce them to a single consonant before vowels, and replace the useful and enlivening *r*, with *l* or *s*. Under this dissection, ICTUS, a blow; PRECOR, I pray; ROGO, I ask; and STRIX, (Persian, tshōkak) an owl, might become respectively ic, lec, sec, tec; which, from the want of the Latin inflecting material, might each have the power of from ten to fifty words, as distinct as RINGOR, I gape; SECO, I cut; and PLICO, I fold. But as STRIX, to be pronounceable, must become something like satalicasa, its Chinese form might be *sa*, as Batavia is *pa*.

§ 7. Similar imitative words may occur in languages the most distinct, without indicating linguistic affinity; as in the names of animals which imitate their cry, like the Chinese beâou, a cat, the voice of which is called miau by the Germans, *m* being a nasal *b*. But an identity of imitative words is not common between languages of different stocks, because they are submitted to the local laws of speech. In English, one who hesitates what to say, is said to *hem and haw*, although he does not use one of the sounds imitated in this translation into speech; whilst the French imitative word *siffler* is different from the English *whistle*, *hiss*, and *whiz*, although the root sif- is a metathesis and permutation of *whiz*, *fiz*. The English imitatives *roar*, *rush*, however natural they appear, need not be looked for in Chinese; nor will Cherokee (in which *p*, *b*, *f*, *v*, are wanting) furnish phonetic equivalents to pop, bob, bubble (*πομφός*), and their cognates in viv-id, vi-olent, vi-gor, *Βί-ος*, *Βί-α*, be, VI-R, VI-REO, VI-S, etc.

§ 8. But whilst imitatives must be compared with caution, if we find that an imitative basis has been not only adopted, but modified (as

far as the genius of different languages would permit) in the same manner, with the same prefixes, having the same power, we will have gone far to prove a common origin in the languages where such a uniformity occurs,—especially between Chinese and the European languages, where the differences are so obvious.

§ 9. In the present essay, a throat exclamation will be traced into European speech, together with its ramifications and growth by means of reduplication, metathesis, and the use of prefixes; to be followed by their Chinese equivalents. Throat sounds are used in various languages, to form words for cough, throat, speech, wailing, cricket, gurgle, emotion, rigid, narrow, action, work, break, noise, pound, fragment, breach, crack, point, thorn, spear, axe, molest, strike, tear, throw, shoot, ray, light, torch, fire, blow, go, extend, etc.

### IRISH.

§ 10. Och, *oh, alas;* cohù, *sorrow;* ochàn, *a deep sigh;* t-achta, *choking;* g-ŭch, *a loud voice;* r-ŭch, *a running, a rushing;* sruch, *a flowing of waters, a stream;* scrìach, *a screech.*

### WELSH.

§ 11. O, *alas, out of, what proceeds;* oi, *well! to proceed;* oc, *from, out of;* og, *what is full of motion or life, youth, a harrow;* (Latin occo, to harrow). The force of the Irish prefix *r*-, appears in Welsh as follows:—

§ 12. rhu, *a loud utterance.*
rhw, *what breaks or grows out.*
rhuo, *to roar, to talk.*
rhueinell, *a clarion.*
rhe, *swift motion.*
rha, *what forces.*

§ 13. uch, *what breaks out, a sigh.*
ig, *a hiccup, a sob.*
och, *alas;* ich, *a squeal.*
ochan, *a groan;* igio, *to sigh.*
achan, *a hymn.*
ag, *an opening, a cleft.*

§ 14. By combining rhu with uch, etc., and using prefixes (as c-, ys-, gw-,) to the compounds, we get the two following series:—

rh-ach, *what is forced out.*
rhoch, *a grunt, groan.*
rhinc, *a creak, gnash.*
rhing, *a creak.*
rhunc, *a snort, a rattle.*
rhych, *a trench.*
rhic, rhig, *a notch, groove.*

c-r-ech, *a scream.*
greg, *a cackle.*
grig, *a low rustle.*
gryg, *harshness, roughness.*
grwng, *a rumbling noise.*
ys-g-rech, *a screak.*
ysgrechog, *a jay.*

§ 15. The reduplication of ig, ich, (and the use of prefixes,) gives (*c* being *k*, as in Latin),

| | | |
|---|---|---|
| ceg, *the mouth, throat.* | cegn, *to glut.* | gwag, *a vacuum.* |
| cegio, *to choke.* | cyngan, *speech.* | ys-gecru, *to bicker.* |
| cecr, *a brawl.* | gw-ich, *a s-qu-eak.* | h-uch, *a sow.* (Pers. khŏk, *a hog.*) |
| cecren, *to scold.* | gwica, *to cry wares.* | p-uch, *a sigh, a grunt.* |
| cocr, *coaxing.* | gwach, *a hole.* | p-ucho, *to sigh, pant, grunt.* |

Compare Angl. cegan, *to call* The p- of p-uch occurs in (de)p-rive, p-lacid, etc.

§ 16. The Welsh root-word lla (akin to rha, § 12,) is a noun meaning, that which *breaks out*, is light, or *clear*. It has various cognates, as llae, *an expanse;* lli, *a flood;* llw, *an exclamation, oath;* llewer, *light;* lloer, *the moon;* llewen, *a focus;* llewyrn, *a meteor;* llwys, *clear, pure, holy;* and with a prefix, g-lwys, *pure, holy, fair;* g-law, *brightness;* golwch, *worship.*

§ 17. By combining lla and uch, we get the series, —

| | |
|---|---|
| llach, *a ray, a slap.* | llwg, *what is bright.* |
| llachar, *gleaming.* | llugan, *a glitter.* |
| lluch, *a throw, a glance.* | llugas, *a dawning.* |
| lluched, *lightning.* | llugorn, *a trumpet.* |
| llig, *what shoots.* | llygad, *eye-sight, eye.* |
| llug, *a gleam.* | llygas, *splendor.* |

§ 18. By combining lla and uch, commencing with the guttural, we get another Welsh series, —

| | | |
|---|---|---|
| gal, *spread out, clear.* | colon, *a peak.* | gawl, *a dawn, holy.* |
| galw, *to call, invoke.* | gall, *energy.* | geli, *a shooting out.* |
| galaru, *to lament.* | gallus, *powerful.* | gelin, *a sprig.* |
| col, cor, *a point.* | golau, *light.* | goliw, *a faint tint.* |
| col-p, *a dart.* | gole, *splendor.* | claer, eglur, *clear.* |

The -p in col-p (Swedish, kol-p, *a dart*) is present in the English gulp, yelp, scalp. The following are Gaelic: —

| | | |
|---|---|---|
| gal, *weeping.* | geal, *fair, bright.* | gaol, *love.* |
| gul, *crying out.* | gilead, *whiteness.* | gealun, *fire.* |
| galan, *noise.* | galla, *brightness, beauty.* | gaoil, *boiling, anger.* |

§ 19. The two preceding series (§ 17, 18,) suggest φ-λέγ-ω, to burn, shine, vex; *φλέγμα, fire,* (f-la-me): English, lo! look, light, call, yell, gul-let, clear, glory, glow: *ἀϝ-γέλλ-ω, to announce; ἀ-γάλλ-ω, to make splendid, to exult:* Irish, găl, *white;* gălăch, *the moon:* Latin, LUCEO,

*to shine;* LUX, *light:* Gr. *λύκος, the sun; λύχνος, a lamp; γ-λαυκ-ὸς, blue, clear,* the L of which appears in *λάω, to look at; λεύω, to see, shine.*

§ 20. The same L (§ § 16, 19,) occurs in the Gaelic la, lo, laoi, *a day;* laom, *f-lame;* li, *color;* leas, *light;* leicc, leug, *a diamond, a gem;* lia, *a flood;* lua, *an oath, water;* lo, *water.* With these (and with rhu, § 12, *r* not being a Chinese element), we may compare the Chinese lê, *clear, bright, happiness;* lek, *bright, clear;* lōng, *fireworks;* lo, *a voice, a sound;* loé, *to converse;* lô, *a gong;* lō, *a drumming in the ear;* laóu, *a noise;* lêw, *a flood;* lē, *to flow rapidly.*

§ 21. From the continuousness of S, s-creak may have been intended for a continuous action: uch, ich, (§ 13,) being continuous, want the explosive sharpness that results from commencing with closed organs, a deficiency which c- (cay) would supply, besides simulating the closed glottis at the *beginning* of a c-ough, at the *end* of a hi-c(cup) during the *continuance* of ch-ok-ing or g-ag-ing, and the *frequentative* action of c-ac-ling, ch-uc-ling, and g-ig-ling.

§ 22. The root of s-c-r-eak is perceived in h-ic-cup, the enlivening *r* gives r-ing, (and the perversion r-ough): Latin, R-IC-TUS, the mouth; RAVCUS, hoarse, harsh; R-OG-O, to ask; Gr. *ῥ-έϝκ-ω,* to snort; *β-ρ-ύχ-ω,* to howl; *κ-ρ-ίζ-ω,* (fut. *κ-ρ-ίξω,*) to c-r-eak; *κρίγή,* a creak, *κ-ρ-άκ-της, κραγέτης,* a crier; Latin, C-R-OC-IO, to croak, leading by successive prefixes, to creak, cricket, crack, screak, screech, click, cluck, clang, etc.; Gr. *λ-ιγ-αίνω,* to cry out; *κ-λ-αϝγή*; Latin, CLANGOR; and gloc-io, to cluck. Starting with the root of ECHO, r- gives r-ixa contention, a t- prefixed (*τρίζω,* to stridulate, in the future tense) *τ-ρ-ίξ-ω,* and an intensive s-, S-T-R-IX, an owl. This agglutination of prefixes shows a close affinity in the structure of Greek, Latin, and English words.

## § 23. GREEK.

1 *ἠχὴ,* sound, clamor.
2 *ἠχὼ,* echo.
3 *εὐχὴ,* a prayer, boast.
4 *ἄϝχω,* to throttle, torture.
5 *ὀξὺς,* sharp, ac-id.
6 *ἀκοὴ,* a sound, the ear.
7 *ἀκούω,* to hear.
8 *ἄχος,* affliction.
9 *κωκύω,* to lament.
(*ἰαῦ, οἴ,* alas.)
10 *ὀϊζὺς,*↓ affliction.*
11 *ἰ-αχ-έω,* to shout.

---

* The initial of this word is akin to the preceding. The mark ↓ indicates that the word is not a primitive form, ζ being probably derived from a guttural, like Sanscrit, Persian, and English *tsh,* which is rarely a primitive.

12 *αἰ-αγμα*, a sigh.
13 *ἰ-ωκ-ὴ*, din of battle.
14 *ὄχ-λος*, a mob.
15 *ἐγ-ὼ*, I, the sp-eak-er.
16 *ἐκεῖ*, there.
17 *ουκ, ουχ*, not.
18 *ὅ-γε*, this; HOC, *γε*, ye-s.
19 *ὀϝκ-άομαι*, I bray.
20 *ὀϝκος*, swelling, bulk.
21 *ὀϝκη*, size, a hook.
22 *ἐγ-είρω*, to arouse.
23 *ἄγε*, come out! hence to *egg*, or *agg* on.
24 *ἀϝ-γέλλ-ω*, to announce.
25 *ἀγάλλω*, to make splendid, to exult; *αἰγλη*, *αγλ-αἰα*, splendor.
26 *αὐγὴ*, light, the eye.
27 *φ-λέγ-μα*, fire, heat.
28 *ἄγη*, respect, envy, hate.
29 *ἀγαυρὸς*, proud, fierce.

*

30 *λ-άκ-ω*, to sound like breaking.[6]
31 *λέγω*, to speak.
32 *λακάζω*, to talk.
33 *λευκανία*, the throat.
34 *χ-λιάζ-ω*,‡ to swell, be full, rush, gurgle.
35 *λιγαίνω*, to cry out.
36 *λίϝγω*, to hiss, whiz.
37 *λὶγνυς*, a smoky fire, smoke.[27]
38 *λ-ιγυ-ηχ-ὴς*, clear sounding.
39 *κ-λαϝγὴ*, clangor.
40 *λυϝγαίνω*, to sob, hiccup.
41 *φ-λάζ-ω*,‡ to stammer.
42 *ἄγω*, to b-r-eak.
43 *οἴγνυω*, to open.
44 *λ-ακ-έω*, to rend, break, resound.
45 *λακτίζω*, to kick.
46 *λάκτις*, a pestle.
47 *λίγδος, ἴγδος*, a mortar.
48 *π-ληγὴ*, a blow.
49 *π-λήκ-της*, a str-ik-er.
50 *λόϝχη*, a spear head, the tip of the t-ong-ue.
51 *λοιγὸς*, destruction.
52 *λειχὴν*, lichen.†
53 *λάχνη*, wool.†
54 *λάκος*, a rag.[101 102]
55 *τ-άγ-υρι*, a minute fragment.
56 *λάχος*, a lot, portion, appearance.
57 *λόχμη*, a bush, thicket.
58 *λυγαῖος*, shady.
59 *λυγρὸς*, sad, weary.
60 *λύγη*, darkness.
61 *λύγος*, a shrub, an osier, flexible.
62 *λυγόω*, to bend, tie.
63 *λοξὸς*, oblique.
64 *τ-όξ-ον*, a bow.
65 *ἀγὴ*, a fracture,[42] a wave.
66 *ἀξίνη*, an axe.
67 *ὄγμος*, a furrow, track.
68 *ὀξετὸς*, a trench.
69 *ὀχὴ*, food, a hollow.
70 *ἀγαρικὸν*, a mushroom.
71 *ἀκάχω*, to molest.
72 *τρ-υχ-όω*, to harass.[4]
73 *αἰκ-ία*, injury.
74 *αἶγδην*, impetuosity.
75 *ἴξαλος*, leaping.
76 *αἶξ, αἶγα*, a goat.
77 *ἀϝκαλὶς*, the arm.
78 *αἰχ-μὴ*, a spear point.
79 *μ-άχ-αιρα*, a sword.
80 *ἀκὴ*, a point.
81 *ἄκαν*, a thistle, brier.
82 *ἄκανθα*, a thorn.
83 *ἀκμὴ*, acme; *ακ-μαὶ*, pimples.
84 *ἔχις*, a viper.
85 *ἐχῖνος*, a hedgehog.
86 *ἀχρὰς*, the wild pear.
87 *στάχυς*, a sp-ike of corn, a plant, offspring.
88 *τέκος*, a child.
89 *στ-ιγ-εὺς*, an awl.
90 *τραχὺς*, rough, harsh.
91 *τριγμὸς*, a shrill cry.[19]
92 *δ-έχ-ομαι*, to tak-e, comprehend.
93 *μηχανὴ*, a work.
94 *δεκτὴρ*, a tak-er.
95 *δάκτυλος*, a finger.
96 *λιχανὸς*, the fore finger.
97 *λείχω*, to lick.[50]
98 *ὀρ-έγ-ω*, to stretch forth.
99 *τ-άγ-ω*, to grasp.[92]
100 *β-ραχ-ίων*, the arm.[98 49]

‡

101 *ῥάγος, ῥάγος*, a rag.
102 *τ-ρῦχ-ος*, a tatter.
103 *β-ραχ-ὺς*, short, little, as if b-rok-en.

---

* *λύα*, discord; *λα-, δα-, λε-*, are intensive, as in *λίαν*, *very*.

† From its broken appearance, — but *κ-ρέκ-ω*, is to *strike*, to *weave*; *κρόκη*, the woof; *κροκὶς*, nap, a lock of wool, threads sticking out of cloth; hence *κρόκος*, crocus, *saffron*, from the conspicuous stigmas.

‡ The force of R in No. [101], etc., (see § 12) is observed in *ὀρούω*, to rush upon; *ὄρω*, to move, excite, arise; *ῥέω*, to flow; *θ-ρόος*, uproar.

104 ῥάκτος, a steep rock.
105 ῥακτήριος, resounding, striking.
106 ῥάχις, the spine.
107 ῥίζα,↓ a root.
108 ῥάχος, a thorn bush.
109 φ-ραγμὼν, a thorn hedge.
110 φ-ρακτὴρ, an inclosure.
111 θ-ριϝκὸς, a coping.
112 τ-ειχέω, to wall, fortify.
113 τεκταίνω, to construct.
114 τεχνάω, to make.
115 ῥωγὰς, split.
116 σ-άγαρις, a battle axe.[46]
117 βράχω, to crash, creak.
118 βρύχω, to howl.
119 ῥόχθος, a loud noise.
120 ῥέϝκω, to snort, snore.[91]
121 ῥύϝχος, a snout.
122 ῥῆγμα, a b-reak, c-rack.
123 ῥηκτὸς, broken.
124 τ-ρ-ώγ-ω, to chew.
125 φ-αγ-εῖν, to eat.
126 φηγός, the beech.
127 τρύγη, corn, pulse.[124]
128 ῥόγος, a granary.
129 κρέκω, to strike.
130 τ-ράγ-ος, a goat.
131 κράκτης, a crier.
132 κ-ράζω, ↓ to c-roak.
133 κ-ρίζω,↓ (fut. κρίξω) to c-reak.
134 φ-ραζω,↓ to relate.[41]
135 φ-ρὶξ, the murmur and rippling of waves.
136 φρίκη, a shuddering.
137 φριξὸς, bristled, rough, curly.
138 θρίξ, hair; [58] *note*.
139 φρύγω, to fry, parch.
140 φρυκτεύω, to kindle.
141 αὔξω, to aug-ment.
142 πακτόω, I make compact, πηγὸς, compact.
143 πάγιος, stiff with cold.
144 πάγος, frost, ice.
145 πάχος, thickness.
146 παχύνω, to render fat.
147 πῆχυς, the upper arm.
148 πυγὼν, a cubit.
149 πυγή, the haunch.
150 πυκνόω, I condense.
151 πυκινὸς, crowded.
152 πυγμὴ, the fist.
153 πύκτης, a b-ox-er.
154 πηκτὶς, a lyre.
155 μαγάδις, a lyre.
156 μάχη, f-igh-t.
157 μέγας, big.
158 μακρὸς, long.*
159 μικρὸς, small.*
160 πόκος, a fleece.
161 πώγων, a beard.
162 πύξος, the box-tree.†
163 πεύκη, the fir, a torch.†
164 πίσσα,↓ pitch, (*pixa?*)†
165 πικρός, pungent, bitter.

## § 24. LATIN.

The following numbers and words correspond, in a general way, with those of the preceding Greek series. Such a reference admits of much variation, a word in one language having affinities with several in another. To keep this in view [42] ICO, I strike, has the number of ἄγω, I break, and its derivative ICTUS, a blow, has that of *αἰκία*, an injury. The name of a singing-bird, [128] FRINGILLA, is placed near

* Whilst crowding on material enlarges an object, pressure and condensation diminish the size of the aggregation. Compare MAGNUS, large, and MACER, lean.

† Πύξος, BUXUS, from its dense foliage, — "most dense" of Plini. "Buttmann makes it very probable that the radical notion of πεύκη is not, as usually supposed, that of bitterness, but of sharp-pointedness, the fir being so called either from its pointed shape, or from its spines." *Liddell and Scott.* Πεύκη, *fir*, is in Latin ABIES, probably for ABIEX, its adjective being ABIEGNUS, as SALIX, *willow*, gives SALIGNUS, *made of willow*.

[31] FRIGUTIO, to twitter; but the bird has a very robust bill, and is a seed eater, hence its number is that of FRANGO, to break. Here there is no real discrepancy; words like *break*, *crack*, being applied both to the sound and its accompanying phenomenon, the ear taking note of the former, and the eye of the latter.

[1] AH, alas, oh.
[12] EHO, ho! V-AH, oh!
[13] S-IC, thus; T-UNC, then.
[13] H-IC, here; H-OC, this.
[13] EX (εκ, εξ), out of.
[15] EGO, I.
[10] AI (*αἰ*), alas; AIO, I say.
[10] EJULO, I wail.
[27] ECCE, behold.[16]
[26] OCULUS, eye.
[27] B-ACCA, berry.
[27] N-IC-TO, I blink.
[27] N-IC-O, I beckon.
[27] SP-EC-IO, I see.
[27] S-AG-AX, seeing easily, ac-ute.
[6] ACHETA, a cricket.
[6] CICADA, a noisy insect.
[30] LOCUSTA, a grasshopper.
[2] ECHO, echo.
[33] V-OX, voice.
[33] V-AGIO, I sq-u-eak.
[33] F-AC-UNDUS, el-oq-uent.
[33] B-UC-INA, a trumpet.
[33] P-OC-ULUM, a cup.
[33] B-UCCA, a mouth, morsel.
[33] M-ICA, a crumb, bit.
[33] MAXILLA, a jaw.
[33] MUGIO, I bellow.
[33] F-AVC-ES, the gullet.
V-AG-INA, a scabbard.
V-ACO, to be empty.
[67] L-AC-UNA, a ditch.
[31] L-ACIO, I call.
[31] LEGO, I depute.
[31] LOQVOR, I speak.
[31] LUGEO, I mourn.
[31] P-IG-EO, I grieve.
[31] N-EGO, I say no.
[31] D-OCEO, I t-each.
[31] FR-IG-UTIO, I twitter.
[31] F-L-AG-ITIO, I demand.
[123] FRINGILLA, a finch.
[139] FRIGO, I roast.
[115] RINGOR, I open the mouth.
[115] STRIGO, I rest, take breath.
[91] S-T-R-IX, an owl.
STRIDEO↓ (*d* for *g*) *τρίζω*,↓ to stridulate.
[91] STRIGILIS, a scraper.
[119] R-IX-A, contention.
GR-AC-ULUS, a jackdaw.
ROGO, I ask, beg.
PROCO, I demand.
PRECOR, I pray.
[115] RICTUS, the mouth.
RUCTUS, eructation.
RAVCUS, harsh.
RUGA, a w-rinkle.
RIGOR (*ῥῖγος*), stiffness.
FRIGEO, I freeze.
FRICO, I rub.
[123] FRANGO, I break.
FRAXINUS, the ash.
PL-ANGO, I beat.
PLAGA (*πληγή*), a blow.
PLECTO, I punish.
PLECTO (*πλέκω*), I plait.
[62] FLECTO, I bend, turn.
[58] FLOCCUS, a lock of wool.
[62] LUCTOR, I wrestle.
[62] LIGO, I tie.
[58] LICIUM, a thread.
[44] LIGO, a hoe, a rake.
P-EC-TEN, a comb.
PLICO, I fold.
[44] LAXUS, sl-ack, wide.
PL-ACENTA (*πλακοῦς*), a cake.
FLACCUS (*βλὰξ*), flaccid.
FL-AGELLO, I whip.
[124] FR-UX, produce.
[125] N-UX, a nut.
[126] F-AG-US, the beech.
[5] AC-EO, to be tart.
[5] ACIES, an edg-e.
[80] ACUS, a needle.[78] [66]
MUCRO, a point.
MACERIA, a garden wall.
[8] EGEO, to ach-e.
[42] ICO, I strike.[47] [123]
[78] ICTUS, a blow.
[42] J-AC-EO, I throw.
[42] OCCO, I harrow.
[116] S-AVC-IO, I wound, kill.
S-UG-ILLO, I strike, revile.
SAVCIUS, sick.
SIGNO, I mark, express.
V-EX-O, I pl-ague, affl-ic-t.
VICTIMA, a victim.
TR-UX, fierce.
L-AC-ERO, I tear.
LACERTA, a liz-ard.
S-AXUM, a rock.
SECO, I cut, wound, go.
SICA, a d-agg-er.
SICILIS, a sickle.
N-EC-O, I slay.

NOCENS, per-n-ic-ious.
NOX (νύξ), night.
NIGER, black.
NUGAE, trifles.
PECCO, I sin.
P-EJ-OR, worse.
42 AGO, I move, drive.
S-AG-ITTA, an arrow.
T-IG-RIS, a tiger.
27 IGNIS, fire.
25 FL-AG-RO, I burn, glow.
FOCUS, a hearth.
FAX, a torch.
118 T-IG-N$^{m}$, a beam.
87 L-IG-NU$^{m}$, wood.
B-AC-ULUS, a stick.
AXIS (ἄξων), an axletree.
GR-AC-ILIS, slender.
L-ONG-US, long.
M-AC-ER, m-eag-re.
V-AG-OR, I wander.
S-EQ-VOR, I follow.
42 FR-EQ-VENS, frequent.
L-INQ-VO, I leave.
F-UG-IO (φεύγω), I fly.
N-IX-OR, I rest on, strive.
114 F-AC-IO, I m-ak-e.
FACIES, appearance.
98 PEGMA (πῆγμα), a m-a-ch-ine.
F-AEC-ULA, dregs.
M-AC-ULA, a stain.
P-IG-MENTU$^{m}$, paint.
F-ING-O, I make.
F-IG-O, I fix.
FICTUS, feigned.
F-IG-URA, shape.
L-OC-O, I place.
L-EC-TUS, a bed.
L-EG-O, I collect.
L-UC-RU$^{m}$, gain.
141 AUG-EO, I augment.
141 M-AC-TUS, augmented.
141 M-AG-IS, more.
157 M-AG-NUS, b-ig.
M-AG-ISTER, a master.
R-EG-O, I dir-ec-t.
P-ANG-O, I fix, agree.
PIGNUS, a pawn.
PACTUS, bargained.
PL-AC-ATIO, a pacifying.
P-AC-O, I pacify.
151 P-AG-US, a village.
151 V-IC-US, a village.
152 P-UG-NUS, the fist, a handful.
158 PUGNO, I fight.
PUNGO, I stick, sting.
πάγουρος, a p-ung-ar, (spiny lobster).
PUGIO, a dagger.
SP-IC-A, a spike.
T-ANG-O, I touch.
T-AC-EO, I am silent.
97 L-ING-O, I lick.
50 LINGVA, the tongue.
92 D-UC-O, to draw, t-ug, g-et.
92 D-IG-NUS, tak-e-worthy.
92 D-EC-ENS, decent.
92 DECUMANUS, great.
92 DICO (δικάζω), I take, give, proclaim, say.
92 DICO, I say, assign.
92 DIGITUS, a f-ing-er.
92 DEXTER, the right hand, m-ight.
92 DECE$^{m}$ (δέκα), ten.
92 INDEX, a sign.
92 INDICO, I show, declare.
42 DEGO, (DE, AGO,) I live.
TR-AH-O, I draw, take.
TR-AC-TO, I dr-ag, str-ike.
V-EC-TO, I convey.
25 LUCEO, to light, glitter.
L-IQ-VEO, to be liquid, clear, plain.
AQ-VA, water.
M-AC-ERO, I s-oak in l-iq-uor.
M-UC-IDUS, slimy.
L-AC-RIMA, a tear.
LACUS (λάκος), a lake.
ST-AG-NU$^{m}$, a pool.
R-IG-O, I irrigate.
S-ICC-US, dry, thirsty.
S-ICC-O, I dry, drain, suck.
SUGO, I suck.
SUCUS, juice, sap, v-ig-or.
SANGVIS, blood, force, race.
V-IG-EO, I live, am active.
F-EC-UNDUS, fertile.
V-IC-TITO, I feed on.
V-EG-ETUS, quick, fresh.
R-EC-ENS, growing, fresh.
RACEMUS, a cluster.
SEGES, seed, corn, profit.
SAGINA, food, fatness.
P-IX, pitch.
P-ING-VIS, fat.
P-EC-TUS, the breast.
P-IG-ER, slow, dull.
P-EC-U, sheep, cattle.
GR-EX, a flock.
58 L-UC-US, a wood.
62 NEXO, I bind, connect.
72 STR-ING-O (στράγγω), I grasp, tie.[62]
62 V-INCO, I conquer.
T-EX-O, I weave, build.
T-OG-A, a gown.
T-EG-O (στέγω), I cover, st-ick away.
S-OC-IO, I join, associate.
MAS (for max ?), a male.
TUSSIS (for tuxis ?) a cough.

## § 25. CHINESE.

Chinese being spoken with a peculiar intonation, the marks of accent and length used in printing it, indicate the tone, and where this is different, but the elements identical, the words are considered to be distinct. In fact it is less of an error to use T for L, than to use a wrong tone. The examples are from Medhurst's dictionary of the Hok-këën dialect, and the orthography English, ch, y, ng, having their power in *chip*, *young*. The examples will be those corresponding to the Welsh, Greek, and Latin, already given, commencing with those which have a reduplicated guttural, as k–k, k–ng, y–k, or its transmutation (with English ch, as in speak, speech,) ch–k.

§ 26. kek, bright; keng, very bright; gâng, bright; gông, sunrise; hông, red; yàng, to illumine; yang, the sun; cheng, brightness; hong, luminous, clear; (sëang, cloth of a light yellow color, as if from sè, cloth, and eng, bright).* Jakutish, tshaghyrgă, to radiate, lighten; tshokyr, flint; tshoχ, a burning coal; dzhangkü, to be clear, transparent. The mind associates a ray, a spear, and a shoot; hence we find

§ 27. kek, a spear; hong, the point of a weapon; keng, a stalk of corn; chek, a blade of grass; yang, young shoots of rice, calamity; yāng, nourishment; yáng, nausea; (seng, to be born, alive).

§ 28. go'k, a peak, the point of a sword, a crocodile; ga'k, a hill; gek, rugged like hills, lofty; gōng, high.

§ 29. yëu'k; a sound, a voice, bright, clear; yúng, to leap, a bubbling fountain, bold; yea'k, to leap; heng, to walk, to travel; (ông, to walk quickly; sëang, hasty); cheng, hasty walking, afraid; hek (and lek), to be afraid; che'k (and tëuk), to advance; (e'k, to lead hastily); hēng, to accompany; hông, haste; hëùng, to hasten. (In German *keck* means pert, bold, nimble; Eng. quick). Jakutish, yk, to hasten.

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* In like manner, it is probable that the Sanscrit root răp'h, *to stir, to break*. Latin, RAP-IO, (Eichhoff, No. 525,) is composed of aR, *to go, to reach*, (E. No. 495,) and ab, *to go*, (E. No. 22,) or āp, *to occupy, to hold*, (E. No. 23.)

§ 30. The following examples, in continuation of the preceding, are to be read across the page. The first column contains the root, to which the prefixes s-(r-)t-, l-, are added in the second, third, and fourth columns. A few parallel forms in Greek, Latin, Welsh, Gaelic, and Hebrew are added, examples in r- being placed with its cognate s-.

§ 31. The force of the Chinese prefixes k-, s-, t-, (l-, see § 20,) is observable in ke, a pearl; to ridicule; to pray; to sell;* kē, to fear; kè, a stalk; proud; hasty; kê, happy; kae, violence; harmony. sē, to look at; to spread out; a connecting thread; ardent; to swear; day-break; a peak; se, an arrow; to wet; silk; spittle; the beginning; sè, power. te, to blame, to kill; té, to revile; to oppose; tè, to extend to; to display; tê, a pond; to walk; tâ, to frisk; to be burnt.

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* When definitions are separated by semicolon, they are represented by different Chinese characters of the same name; when by a comma, they define a single character.

As the Latin final *m* indicated a nasal vowel, it is printed as in STAGNUᵐ, that it may not have the prominence of a real (and a labial) consonant letter.

The examples of Jakutish (yakutish) are from Böhtlingk, and in the absence of the proper types, his Russian orthography has been roughly turned into English. It could not have been done critically without considerable explanation, and the same remark applies to the few Hebrew words introduced.

Should the suggestion that ABIES is from ABIEX be correct, the following table may be constructed: —

| | |
|---|---|
| A B I E G N U S, | *of fir.* |
| A B I E .. .. .. S, | *the fir.* |
| P I .. C .. .. S, | *pitch.* |
| F .. A C .. .. S, | *a torch.* |
| F .. O C .. U S, | *a hearth.* |
| π ε ύ κ .. η .., | *the pine.* |
| S-P I .. SS .. U S, | *dense, etc.* |

Here SPISSUS is probably for *s-pic-sus*, from the root of *pac*, no. 142.

In the following examples, a few of the words are not placed in the column with those having the same initial — for the purpose of accommodating modifications of idea. Thus, Hungarian *szak*, § 36, stands in the first, instead of the second column.

| √ | S— | T— | L— |
|---|---|---|---|
| § 32. eng, *clear, bright.* ek, *the brightness of fire.* (Latin, IGNIS, *fire.* Gaelic, ogh, *pure;* eag, *moon;* ece, *clear;* uige, *a jewel.* Hung. ég, *the stars.* Jakutish, öng, *color;* ing, *red on the cheeks.*) | seng, *bright, to burn; sunrise.* song, *clear, pleasant, grand.* (Welsh, rhaca, *a show.* Gaelic, eugas, *likeness.* Jakut. saχ, *to strike fire.*) | teng, *a lamp.* t'hëung, *dry and hot.* t'hun, *a spark.* tông, *red.* sec, *dry.* (Lat. SICCUS. W. têg, *clear, fair.*) | lēng, *good, fine.* lóng, *the appearance of fire.* lóng, *bright, clear.* lëu'k, *green.* (Lat. LUX, § 19. Heb. LăHăb, *a flame, a sword-blade;* LaHat', *to burn,* § 23.[27]) |
| êng, *a fire-fly.* | seng, *a star.* | t'hong, *the sun darkened.* | lêng, *the rising sun,* § 17. |
| § 33. eng, *a flower.* êng, *flowery.* ōng, *to prosper, bright.* | seng (and sey), *luxuriant herbage.* (Heb. răɣăn, *to sprout leaves;* shāghāh, *to grow.*) | t'hok, *bamboo shoots; to burst out.* te'k, *a sort of reed.* (W. tug, *prosperity.*) | lông, *overgrown grass.* lëu'k, *high grass.* (Welsh, llig, *what shoots.*) |
| § 34. éng, *beards of grain, an awl;* a'k, *a spindle.* ong, *a wasp.* (L. ACUS, *a needle,* § 23[5]; ACULA, *an awl.* Gael. acht, Hung. szeg, *a nail.* Turkish, aug; Jakut. oχ, *an arrow;* igi, *a file.*) | sek, *to stab, a sting.* sok, *a lance, a spear;* san,* *skewers.* (Heb. răɣăɣ, *to break;* răqăq, *to spit.* Lat. SAG-ITTA. Gr. ῥάχος.[108] W. such, *a snout.* rhuch, *a husk.*) | tek, *an arrow point.* teng, *a nail.* t'hek, *to slaughter.* (Lat. TANGO, *I touch, at-tack.*[92] Heb. tăqăɣ, *to strike.* Jakut. tong-syi, tshok-yi, *to beat, knock;* dzhang, *pestilence.*) | lêng, *any thing pointed and angular.* lông, *to pierce.* lōng, *corner of a hill.* long, *thin, meagre.* (Lat. LINGVA, *the tongue.*[50] Sanscrit, nakk, *to pierce;* naç,‡ *to destroy.*) |
| § 35. êng, *a grave;* (ὄγμος, *a furrow.*[58]) ong, *hump-backed.* (Gaelic, aighe, *a hill;* acha, *a mound.*) | sèk, *the hollow of a grave.* sëung, *high; the point of a hill.* sëûng, *a fir-tree.* sëáng, *to ascend, exalt.* (Heb. răghăm, *to heap up.*) | teng, *a mound.* teng, *to ascend, ripen.* téng, *the top.* (Welsh, rhic, *a groove;* rhych, *a furrow.*†) | lêng, *a large mound.* lóng, *a tomb.* (W. lloc, *a mound, a dam.*) |
| § 36. e'k, *the noise of splitting.* (Latin, IC-TUS, *a blow.* Greek, ἄγω, *I break.*[42] Hungarian, ék, *a wedge;* szak, *a fragment.* Jakut. ang-y, *a part;* ang-ai, *open;* ong-oi, *an aperture.*) | sok, *to cut off, to split wood.* (Heb. săhhăph, *to scrape.* Lat. SEC-O, *I cut off.* ῥωγὰς, *split.*[116] W. sig, *a shatter, a bruise;* rhecio, *to hackney.* Heb. rĕhheh, *a mill-stone.*) | tëuk, *to hack, a hoe.* tok, *to scrape, to hack.* te'k, *any thing made shorter.* (W. toc, *what is abrupt;* tocio, *to d-ock;* twc, *a cut.* Jakutish, löng, *split wood.*) | lok, *a sabre wound.* lek, *to cut, scrape; strength.* lēng, *to cut off.* lâng, *to beat, strike.* (Lat. LIGO, *a hoe.*[44 80] Heb. răχăsh, *to strike with the foot.*) |
| § 37. ēng, *to s-ing.* eng, yung,* *the singing of birds.* èng, *the sound of hallooing.* àng, *disorderly.* | seng, *a flute.* (Gr. ῥόχ-θος, *a loud noise.*[91] Lat. RIXA, *contention.* Jakutish, sang-a, *voice, outcry.*) | teng, tin, tang,* *a t-inkling.* tông, *an echo.* tong, *the sound of a drum.* t'hong, *the noise of water.* tóng, *the noise of falling in water.* | lông, *the tinkling of gems.* lōng, *to strike against; the humming of birds.* lèng, *a small bell.* lëûng, *the sound of a drum.* (Jakut. lyngkyr, *a clanging.*) |

| | | | |
|---|---|---|---|
| § 38. **ak**, *a ca-ck-ling.* **ek**, *the noise of l-augh-ing.* (Gael. ac, *speech*; oc, *a poet.* Jakutish, ōghüi, *to choke.*) | **sek**, *a chirping.* (Hung. tik, tyúk, *a hen.*) | **tak**, **chëuk**, *the noise of calling fowls.* **t'hek**, *to vociferate.* **t'hëuk**, *to rail at.* **tëuk**, *to thump.* **tok**, *to beat.* | **lek**, *a kind of flute.* **lek**, *the noise of water.* |
| § 39. **èng**, *to reply.* **yín**,* *to promise.* **yîn**, *to say, to declare.* **yín**, *the sound of thunder*; (ἠχῶ, *echo*,1 6 11–14. Jakutish, *aχ*, *to count, to tell.*) | **seng**, *a voice, a noise.* (Heb. rāhăm, *to make a noise*; răχăm, *thunder*; rēχă, *outcry.* Lat. ROGO, *I ask.* Ger. sag-en, *to say.* W. rheg, *an utterance.*) | **têng**, *to warn.* **t'héng**, *to boast.* **teng**, *a clap.* **tëûng**, *reiterated*; **ek**, *a stoppage in the throat.* (Lat. DIC-O, *I say*; TUSSIS, *a cough*, for TUXIS? W. tâg, *a strangle.*) | **lēng**, *talkative.* **leng**, *to command.* **lêng**, *to insist upon.* (Gr. λέγω, *I speak* 30–35; λόγος, *a word.* Lat. LOQ-VOR, *I sp-eak.* LOCUSTA, *a stridulating insect.*) |
| § 40. **êng**, *water flowing back.* **ang**, *overflowing.* **ak**, *to irr-igate*; **ak**, *to drip*; **yúng**,* *a fountain*; **yûng**, *water flowing quietly.* (Latin, AQ-VA, *water.* Jakut. ygyt, *an overflow.*) | **seng**, *a rising of water.* (Heb. rāhăt, *to flow.* W. soegi, *to steep*; swg, *a s-oak.* Lat. RIG-O, *I irrigate.* Jakutish, sīk, *moisture, dew.*) | **tông**, *a pond.* **têng**, *a dam.* **tek**, *the appearance of water.* **tëàng**, *to inundate, the tide.* **teēng**, *brimful.* (Latin, S-TAG-NUM, *a pond*; STAGNO, *to inundate.* Jakutish, toχ, *to pour out.*) | **long**, *a wave.* **lêng**, *superfluous.* **lek**, *overplus.* (Lat. LACUS, LIQVIDUS. Heb. logh, *a deep cavity.*) |
| § 41. **ek**, *a cord, a series.* | **sàn**,* *a thread.* **sëèn**, *a thread, connecting line.* **sek**, *fine cloth.* (W. syg, *a chain.* Lat. SOC-IO, *I join.* Heb. răχăs, *to bind on, or to*). | **tek**, *to tie.* **teng**, *a cord.* **t'hóng**, *a thread, a line.* | **lok**, *joined, a thread.* (Lat. LIG-O, NEC-TO, *I tie*; LIC-IUM, *a thread.*) |
| § 42. **óng**, *to go*; **eng**, *to encounter.* (Lat. AGO, *I move, drive.* Gael. eigean, *force*). | **sëang**, *to wound.* | **te'k**, *to oppose.* **tong**, *to run against.* **tëu'k**, *to advance.* (Jakutish, yk, *to hasten.*) | **lëu'k**, *to kill.* |

* The vowel *a* generally requires *n* after it, by a law which, out of the English "hang," would be likely to make *han* or *heng*. Similarly "ing" might become *yin*, and "ung" *yung*. Among the root words of the first column are ang, eng, ong, but not *ung*, *ing*; *ag*, *og*, *eg*, *ok*.

† This an example of the *polarity* of words, like the English *dyke*, a mound, and an excavation.

## 2. Supposed Runic Inscriptions. By Dr. A. C. Hamlin, of Bangor, Maine.

I have the pleasure of presenting to your notice some casts in plaster of a supposed Runic inscription, which appears upon a ledge of hornblende on the island of Monhegan, off the coast of Maine.

It was my first intention merely to present these casts, without making at present any remarks, but as I have been requested to express my opinions, I will endeavor to give some explanation.

I will not venture to say that these characters are Runic, but will only suggest the probability of their being made by some illiterate Scandinavian, whose knowledge of the Runic form was very imperfect. If they are recognized as Runic, they belong to that compound, complex, and pointed class which renders an interpretation extremely difficult. The pointed class, however, belongs to those times in which the Northmen are supposed to have visited our shores,—the tenth, eleventh, and twelfth centuries. The earlier the rune the more simple it was in form and the more easy of translation, but the modifications and corruptions of later periods have confused and changed the character in a great degree. There were complete monographs formed by many runes clustered upon a single stem, and with such confused and irregular lines that interpretation was almost impossible. As illustrations of the subject I have drawn, upon the blackboard, some examples from the Binderuner and from the pointed class—a line of marks from Sodor; another from a brooch found at Largs; another from the Ferrœ Islands, and still another from the Kobelicher Uune.

To give an example of the difficulty with which these Runic scrawls were translated, I will relate the instance connected with the assassination of Snorre Thurleson. A note written in Runes, and warning Snorre of the danger of assassination was sent to him, but neither he who was so justly titled the Northern Herodotus, and who was so deeply versed in the lore, nor any of his attending friends were able to interpret its meaning.

There is among the Icelandic accounts of the early voyages to this country, a narration which serves to support the Scandinarian theory of this inscription.

Lief the Fortunate sailed in the year 1000 with thirty-five companies in search of those lands which Bjarne had asserted that he had seen in the distance. After passing Newfoundland, which they called Helluland and Nova Scotia, to which they gave the name Markland, they arrived at an island, after sailing two days and nights. This island may be supposed to have been Monhegan, from the following circumstances. The Northmen saw on the horizon mountains blue with distance. Such the Camden Mountains appear to the observer at Monhegan. The island lay direct east from the main land. This is the position of Monhegan. From this island they sailed into a river close by, and were wafted by the tide into a lake whose waters teemed with the largest and finest salmon. Near by they built their booths, which they called Liefsbudir, and passed the winter.

This river is well represented by the Kennebec, which flows into the ocean close by Monhegan, and Merry-Meeting Bay, the so-called confluence of the Kennebec and Androscoggin Rivers corresponds admirably to the lake before mentioned. Moreover, I am informed by Mr. Williamson, the historian of the State, that about two centuries ago, the early settlers, when clearing the lands on the banks of the Kennebec above its confluence, discovered what appeared to be the remains of chimneys and mouldering ruins, over which grew an ancient forest. These may have been the remains of Liefsbudir, — the relics of seven centuries.

If this scrawl was not made by Lief or his companions, it may have been made by Karlsfne, during the voyage made in search of the lost Torhall, when sailing north from Vineland he came to lands which presented in every view noble and majestic forests; or, perhaps, by Thorwald in his expedition in the direction of Maine in the year 1004.

For three centuries the Icelandic accounts maintain that the Northmen visited our coasts, and it is not improbable that some of the bold Vickings were attracted to this island whose advanced position and lofty heights presented the earliest view of land to the mariner approaching the coast of Maine, and here they may have rudely attempted to commemorate their discovery, or inscribe hurriedly to the memory of a departed comrade.

I have little doubt but that the rock on which this inscription occurs was fissured at first somewhat by nature, and that the advantage was perhaps embraced by the Scandinavian, but I would like to inquire of

geologists whether crystallization, could, by its fissures, form this long series of characters; and precluding the theory of diluvial or glacial agency, whether any one would dare to ascribe them to that force hidden and mysterious which Camerarius and Tournefort were wont to call the play of nature.

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# PRACTICAL SCIENCE.

## I. MECHANICS.

1 On Efflorescence from Brick Masonry. By Lieut. E. B. Hunt, U. S. Corps of Engineers. (In the form of a letter addressed to Professor E. N. Horsford.)

My dear Sir. — I herewith inclose a quantity of efflorescent salt, scraped from the surfaces of brick masonry at Fort Adams, Newport. This salt, as I have already informed you, is highly destructive to the bricks on which it appears, and whoever can discover a complete preventive against its formation, such as to admit of an easy application in practice, will lay engineers and builders under perpetual obligation. I have thought it might be one step towards so desirable a result if you would call the attention of such chemists as may be in attendance at the Albany meeting to this important problem.

The facts are briefly these: brick masonry laid in hydraulic mortar, and exposed to the action of sea air, soon exhibits an efflorescence over the entire exterior surface. The efflorescent crystallization first forms under the outer, hard coating of the brick, and then an exfoliation of brick scales results. The harder crust being gone, each successive crystallization throws off a portion of brick dust, until in a few years an inch or two, or even whole bricks, will be disintegrated. The softer bricks are more rapidly destroyed, but none wholly escape. At Fort War-

ren the intrados course of arch bricks is laid in fat lime mortar, because the effect of hydraulic lime has been found to be very great in inducing this efflorescence. The same type of action as in Brard's process for testing the durability of building materials, is obviously at work in the successive exfoliations of brick masonry. The origin of the efflorescent salt is, doubtless, in great part from the hydraulic cement and brick, but there is not that precise knowledge of facts which ought to be attained in so important a matter. The whole problem needs thorough investigation at the hands of chemists, for it is altogether a chemical one and not one for the engineer. The only theory of causation of which I am aware, is that of General Totten, the chief engineer, who reasons thus in the premises. *Drying* is an essential condition for all efflorescent crystallization. By saturating or coating with substances strongly absorbent of moisture, the dryness necessary for efflorescence may be prevented. Solutions of soft soap, chloride of calcium, bitter water, etc., on trial seem to obviate efflorescence in small pieces of brick, but give unsatisfactory results in large masonry masses. This theory, ingenious though it is, seems too much like an application of main strength, and certainly is rather treating a symptom than the disease. This efflorescence is the result of certain chemical reactions in the masonry masses; and the normal remedy would seem to lie in a clear tracing out of these reactions, and in the use of some new ingredient to prevent or modify the combining processes leading to the destructive crystallization. Any method, not chemical, would seem of doubtful efficacy, and no chemical process has yet been employed. By an appeal to the multitude of chemists, it is possible that some one may hit on the fortunate *stabilitator* of existing combinations, or *divertor* from efflorescent combinations. It would be difficult to estimate the annual value of a process answering this requirement with practical facility; but it would be of immense benefit, even on our fortifications and light-houses alone.

Our hydraulic limes contain soda and potassa, which seem to penetrate the brick, under the influence of the sea air, and thence to protrude under new combinations in crystals of the character now transmitted. I have seen two or three embrasure soles, which had been for several years essentially unventilated, on which a crop of filamentous crystals as delicate as cotton wool, formed a coating of about one inch

deep. In most instances, wet weather runs these fine crystals into a mass or crust, from which new ones again form in dry weather. Whether the fact that the efflorescence in question is limited to the seaboard, finds an adequate explanation in the fogs and moisture of the sea exposures, I cannot say; but this cause would seem to be inadequate, and if so, the saline ingredients of sea-water must take part in the process. The transfer of sea salts in spray borne by the wind, is not to be overlooked. In this connection it may be well to call attention to the bearing of the experiments by Vicat and others, on the destructive action of sea-water on certain mortars, recorded in the *Comptes Rendus* and elsewhere.

It is a general fact, that the chemistry of mortars and cements needs additional investigation; but this special problem of efflorescence from brick masonry is one more urgent than the others, as the lack of a proper solution is, to a considerable extent, prohibiting seaboard brick masonry, and compelling a resort to more expensive stone constructions.

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## II. MISCELLANEOUS.

1. ON SYSTEMATIZING THE ABBREVIATIONS OF TITLES OF PERIODICALS, TRANSACTIONS, ETC. By Lieut. E. B. HUNT, U. S. Corps of Engineers. (In the form of a letter to Professor A. D. Bache.)

IN preparing, under your direction, an Index of the titles of papers on subjects involved in the operations of the Coast Survey, gathered from all the Scientific Periodicals, Transactions, Memoirs, etc., to which I can obtain access, one unanticipated difficulty has again and again perplexed me. Every title which I take out must contain an abbreviation of the title of the work from which it is taken; hence I have been obliged to write many thousands of these abbreviations while gathering the materials for this Coast Survey Index. It is therefore

a matter of considerable moment that these abbreviations should be as brief as possible while serving their primary purpose. The special difficulty to which I refer is, that there is no authentic code of abbreviations in general use, and that many of those particular forms which I have encountered are long, unwieldly, indeterminate, and conflicting. In many instances I have to coin abbreviations, and in many others there are insuperable objections to such as are now more or less in vogue.

This subject is more important than it might at first appear, for these abbreviations are not only written and printed thousands of times each year, but every cultivator of science must, as a part of his special training, become familiar with the abbreviations which concern his own departments of research, as a kind of special alphabet. Hence the abbreviated forms ought to be as short as possible without losing distinctness, to save needless writing and memorizing. This will be better appreciated when we bear in mind that the list of Agassiz and Strickland contains one thousand two hundred and eighty-four titles of acts, journals, and collections of papers on zoölogy and geology alone, without being complete even on those subjects, while each of these titles must probably have one or more abbreviations in use. We ought not to forget that we are even now but at the beginning of scientific expansion, and that each succeeding year is bringing into being accessions to the long array of scientific records. It is therefore of the greatest prospective importance that principles for abbreviating titles should now be settled, and that practice should as rapidly as possible be brought to a uniformity based on these principles. In 1856 we should bear in mind that the year 2000 is to come, and that then the records of science will be found under at least a myriad of separate periodical titles, and each series will contain matters for future reference, just as we now refer to the various early series of Transactions for the investigations of our predecessors. The results, on being aggregated, would doubtless make a proper subject for publication by the Smithsonian Institution. It seems to me that some plan of this general character would be feasible. Should the American Association share this impression, it is in its power to initiate the measure, and test its practicability with no fear of bad results. The demand of coming generations will be for freedom of memory, and our duty is to make their mnemonic burdens a minimum.

I will cite here a few instances, and these not the worst, to show how unsettled and chaotic our existing practice of abbreviation is. The American Journal of Science is abbreviated to

*Am. J. Sci.*, by Prof. Dana, one of the editors.
*Am. J.*,
*Amer. J.*, by Agassiz and Strickland, in Index
*Amer. Jour.*,
*Jour. of Sci.*, by Poole, in his Index.
*Sill. Am. J.*, by Liebig and Kopp, in Annual Report, etc.
*Sillim. J.*, by Dr. Schubarth in his new Repertorium.

The Philosophical Transactions of the Roy. Soc. London, are abbreviated: —

*Phil. Tr.*, by Agassiz and Strickland.
*Phil. Trans.*,
*Philos. Transact.*, by Reuss, in his Repertorium.
*Ph. tr.*, by Dr. Young, in his Index.

The Comptes Rendus as follows: —

*Compt. Rend.*, by Liebig and Kopp.
*Compt. r.*, by Schubarth.
*C. r.*,
*C. R.*,
*Comptes Rendus*, by Agassiz and Strickland.
*Compt. Rend.*,

The French Academy and Institute Memoirs are thus abbreviated: —

*Mem. de Paris.*, by Reuss.
*A. P.*, by Young.
*S. E.*,

*Mém. Acad. Sc. Par.*,
*Mém. Acad. des Sc.*,
*Mém. Sav. étr.*, by Agassiz and Strickland.
*Mém. s. Prés. à l'Acad.*,
*Mem. Inst.*, is common for the later Memoirs.

This chaotic diversity is common to nearly all abbreviations in the above-cited works, where they must have received rather special

deliberation, and by referring to individual modifications by separate investigators, a perfect Babel of usage will be found. That this is a real evil, I assume none will question. Can it be corrected, is a question on which different opinions will probably be found to exist. Certainly correction cannot come without some effort, and without the aid of time. There is time enough; there ought to be effort enough. Things cannot be worse, for there is now nothing fixed. Conservatism has nothing to fear in this instance.

It has occurred to me as a plan which would stand a respectable chance of success for the American Association to initiate a reform by consigning the subject to a special committee with instructions to invite, in behalf of the Association, the coöperation of other countries concerning their own periodicals, etc. Thus, for instance, the Am. Assoc. might fix such abbreviations for all American scientific issues. It might by correspondence invite the coöperation of the British Association or Phil. Soc. for British periodicals, etc.

Some principles of abbreviation might here be elaborated, but I shall only say in brief: First, that abbreviations should be as brief as possible without becoming obscure. The motto should be, "Abbreviations that are abbreviations." Secondly, only the leading, characteristic words of a title should find place in an abbreviation. Connecting particles should be thrown out. The possessive or genitive form, which is by far the most frequent, can be easily disposed of by using the apostrophe or possessive sign for *of* or *of the*. Thus, Am. J.' Sci.; J.' Soc.' Arts. Thirdly, certain words of very frequent occurrence should be reduced to their initial as an abbreviation; as J. for Journal; M. for Memoirs; N. for New, Nouvelle, Nuovo, Neue, Nova; others to two initials, as Ph. for Philosophical; Tr. for Transactions; An. for Annals; Ac. for Academy, etc. In general the abbreviation for the same word, when frequently occurring, should be constant and a practical minimum in all combinations, and when possible, the same in different languages. Fourth, location should, as a general rule, enter each abbreviation in some form; as, M.' Ac.' Par. for the Paris Academy Memoirs; Am. Ph. Tr., American Philosophical Transactions. These hints will suffice to show that there are principles in this matter which should be carefully elaborated and weighed.

It may be that the coinage of abbreviations under compulsion which has fallen to my lot, leads me to attach an undue importance to the

subject, but I am confident that a like experience would make most persons quite as desirous of seeing an *established code of abbreviations for all the world* as I have become.

Very truly, yours, &c.
E. B. HUNT, Lieut. Corps of Eng's.

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The following papers were presented and most of them were read. They are not printed, because no copy was furnished for publication:—

## I. MATHEMATICS AND PHYSICS.

1. The Elements of Potential Arithmetic. By Benjamin Peirce.
2. Analytical Discussion of the Motion of a Body under the Action of Central Forces. By Benjamin Peirce.
3. Morphological Discussion of the Laws of Central Forces. By Benjamin Peirce.
4. Motion of a Body upon a Solid of Revolution, when the Force is directed towards a point upon the Axis. By Benjamin Peirce.
5. On the Increase of Accuracy in the Mean Result, by Augmenting the number of Observations. By Dr. C. H. F. Peters.
6. On the Interpretation of some Cases of Apparent Geometric Discontinuity. By J. B. Cherriman.
7. Note on the Rotation of a Rigid Body. By J. B. Cherriman.
8. The Fundamental Numeric Series, and Divergence of Radiating Parts, reduced to a Simple Organological Idea. By Dr. T. C. Hilgard.

9. Report on the Present State of Organic Chemistry. By Dr. Wolcott Gibbs.

10. On the Advantage of Observing a Lunar Spot instead of a Limb, in transits, for determining the Difference of Longitude. By Dr. C. H. F. Peters.

11. Researches concerning the Comets of 1783 and 1793. By Dr. C. H. F. Peters.

12. On the Next Appearance of the Periodical Comet of Thirteen Years. By Dr. C. H. F. Peters.

13. On the Physical Peculiarities of Comets. By Stephen Alexander.

14. A Report on the New Methods of Observation now in use at the Cincinnati Observatory: —

   1. New method of right ascension, as to its limit of accuracy.
   2. New method of declination, as to its limit of accuracy.
   3. New method of determining personal equation and personal error.
   4. New method of determining instrumental errors.
   5. New method of determining clock errors.
   6. Observations on changes of figure of materials.

   By O. M. Mitchel.

15. On the Results of the United States Astronomical Expedition to Chili, for the Determination of the Solar Parallax. By B. A. Gould, Jr.

16. On some Special Arrangements of the Solar System, which seem to Confirm the Nebular Hypothesis. By Stephen Alexander.

17. Tidal Currents in Saturn's Ring. By Benjamin Peirce.

18. On the Relative Age of the different portions of the Moon's Surface, and the Catastrophe to which a large portion seems to have been Subjected. By Stephen Alexander.

19. Further Investigation relative to the Form, the

MAGNITUDE, THE MASS, AND THE ORBIT OF THE ASTEROID PLANETS. By STEPHEN ALEXANDER.

20. ON TABLES OF THE ASTEROIDS. By F. BRÜNNOW.

21. ON TEMPORARY STARS, AND THE SPHEROIDAL ORIGIN OF THE FORMS OF CLUSTERS AND NEBULÆ. By STEPHEN ALEXANDER.

22. ON THE PHENOMENA OF THE DISCHARGE OF ORDINARY ELECTRICITY. By JOSEPH HENRY.

23. REMARKS ON THE USE OF THE ANEROID BAROMETER.

24. ON A MODIFICATION OF NOREMBURG'S APPARATUS. By SANDERSON SMITH.

25. REPORT ON THE OBSERVATORY AT TORONTO. By J. B. CHERRIMAN.

26. ON THE PRODUCTION OF ROTARY CURRENTS IN AIR AND OTHER GASES; WITH A SPECIAL ILLUSTRATION OF A ROTARY CURRENT RENDERED LUMINOUS BY FLAME AND INCANDESCENT CHARCOAL. By DR. D. B. REID.

27. ON THE FORMATION OF AIR BUBBLES BY DROPS FALLING ON THE SURFACE OF WATER, ETC. By WILLIAM B. ROGERS.

28. ON CERTAIN MOVEMENTS OF PONDERABLE BODIES, AND CERTAIN SOUNDS WHICH CANNOT BE TRACED TO ANY KNOWN PHYSICAL CAUSE. By DR. HARE.

29. ON THE HISTORY AND THEORY OF THE INSTRUMENTS KNOWN AS ROTASCOPES, GYROSCOPES, ETC. By WILLIAM B. ROGERS.

30. ON THE FORMS OF THE ATOMS OF THE SIMPLE SUBSTANCES OF CHEMISTRY, AS INDICATED BY THEIR ATOMIC WEIGHTS. By STEPHEN ALEXANDER.

31. RESEARCHES ON THE AMMONIA-COBALT BASES. By DR. WOLCOTT GIBBS, AND DR. F. A. GENTH.

32. REMARKS ON OZONE OBSERVATIONS. By WILLIAM B. ROGERS.

33. On the Modifications of Sesquioxide of Chromium. By E. N. Horsford.

34. On the Waters of the St. Lawrence and Ottawa Rivers. By T. Sterry Hunt.

35. Notice of a Locality of Gigantic Crystals of Allanite, with Specimens. By William P. Blake.

36. On a Possible Modification of one of the Methods of Ascertaining the Density of the Earth. By Stephen Alexander.

37. Discussion of the Terrestrial Magnetic Elements for the United States, from Observations in the Coast Survey and others. By A. D. Bache, and J. E. Hilgard.

38. Notice of Observations to Determine the Cause of the Increase of Sandy Hook, made by the Coast Survey, for the Commissioners on Harbor Encroachments of New-York. By A. D. Bache.

39. Notice of Observations to Determine the Progress of the Tidal Wave of the Hudson River, made by the Coast Survey for the Commissioners on Harbor Encroachments. By A. D. Bache.

40. On the Annual Duration of Sunlight on the Earth in Different Latitudes. By L. W. Meech.

41. On the Altitude and Physical Structure of the Appalachian System in the Region of the Black Mountains in North Carolina, compared with those of the White Mountains in New Hampshire. By A. Guyot.

42. Observations on the Andes in Bolivia. By J. R. Loomis.

43. The Plan of Reduction of the Meteorological Observations reported to the Smithsonian Institution, adopted by the Secretary. By James H. Coffin.

44. On an Improvement in the Anemometer. By Charles Smallwood.

45. Description of an Unique Form of Hail or Sleet. By Edward Hitchcock.

46. A Brief Exposition of the Absurdity of the Doctrine which represents that any Storm can be a travelling Whirlwind, unless as a Consequence of Centripetal Currents; or that if due to such Currents, it can have a diameter much more than eighty-one times the height of the Stratum of the Atmosphere within which it may be Generated. By Dr. Hare.

47. On the Meteorological Phenomena during the Epidemic of 1855, at Portsmouth, Virginia. By Nathan B. Webster.

## II. NATURAL HISTORY.

48. On some Points in the Geology of the Upper Mississippi Valley. By James Hall.

49. On the Carboniferous Limestones of the Mississippi Valley. By James Hall.

50. Generalities of the Geology of Oregon and Northern California. By J. S. Newberry.

51. The Metamorphic Action of Silicious Thermal Springs. By J. S. Newberry.

52. Sketch of the Progress of Geology in Alabama. By M. Tuomey.

53. The Permian and Triassic Systems of North Carolina. By Ebenezer Emmons.

54. Some Observations on the Coal-Fields of Illinois. By R. P. Stevens.

55. Notice of a Remarkable Instance of Inclined Stratification in Warren county, New York. By J. D. Whitney.

56. Lateral Disturbance in the Surface Strata in the Sandstone Quarries of Newark, New Jersey. By Edward Hitchcock.

57. On some Euphotides, and other Felspathic Rocks. By T. Sterry Hunt.

58. On the Serpentines of the Green Mountains, and some of their Associates. By T. Sterry Hunt.

59. Observations on the Geology of the Region between the Mississippi and the Pacific Ocean, with a Map. By William P. Blake.

60. On the Results of Collections of Fossils during a period of Ten Years in the Limestones of the Lower Helderberg. By James Hall.

61. Proofs of the Protozoic Age of some of the altered Rocks of Eastern Massachusetts, from Fossils recently discovered. By William B. Rogers.

62. The Deposits of Fossil Fishes and Reptiles of Linton, Ohio. By J. S. Newberry.

63. The Tertiary Flora of the Upper Missouri. By J. S. Newberry.

64. On the Geological Position of the Remains of the Extinct Peccary of the North-west. By J. W. Foster.

65. Together with some Observations on their Dentology. By Jeffries Wyman.

66. Description of a Fossil Shell found in the Sandstone of the Connecticut Valley, probably belonging to the Genus Spherulites. By E. Hitchcock, Jr.

67. Exhibition of Fossil Cetacea from Maine. By A. C. Hamlin.

68. Mud-nests of the Tadpole, Recent and Fossil. By Edward Hitchcock.

69. On Animal Development: Part I. The Egg; Part II. The Embryo; Part III. One-celled Animals. By Louis Agassiz.

70. On Viviparity and Oviparity. By Louis Agassiz.

71. On the Classification of Turtles. By Louis Agassiz.

72. On the Organization of the Acanthocephala. By D. F. Weinland.

73. On the Influence of Light and Water on the Direction of the Plumule and Radicle in the Germination of the Seed. By James Dascomb.

74. Queries relative to some Indications of Human Instinct, as Illustrated by Primitive Arts. By Daniel Wilson.

75. The Value of Physical Conformation as an Element of Ethnological Science. By Daniel Wilson.

76. Considerations upon the Evidences of the Early Voyages of the Scandinavians to this Country, and upon the Cosmical Myths supposed to relate to America. By A. C. Hamlin.

# EXECUTIVE PROCEEDINGS

OF THE

# ALBANY MEETING, 1856.

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## HISTORY OF THE MEETING.

THE Tenth Meeting of the American Association for the Advancement of Science was held at Albany, N. Y., commencing on Wednesday, August 20, and continuing to Thursday noon, August 28.

The number of names registered in the book of members in attendance on this meeting is three hundred and eighty-one. Two hundred and six new members were chosen, of whom all but thirty-eight have already accepted their appointment, paying the assessment and signing the constitution. Thirty-one others have joined the Association by virtue of Rule 2 or 3. Seven others have paid, without a formal election, or signing the constitution. One hundred and forty-six papers were presented; most of which were read, but only a part have been printed. Some were thought unworthy of publication, and, in other cases, copies have not been furnished by their authors.

The sessions of the Association were held in the capitol of the State.

The meeting was opened by a prayer from Rev. William B. Sprague, D. D. Then the President, Professor James Hall, made the following Address: —

GENTLEMEN OF THE ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE:—On taking the chair as President of this Association, I should do injustice to my own feelings were I not to express to you my sincere and heartfelt appreciation of your kindness and confidence in honoring me with your choice,—esteeming that expression of your regard both as a personal favor and as a tribute to the science in whose cause I am the earnest devotee and laborer. Left to myself I could never have assumed the position or its responsible duties; but your partiality almost makes me forget my own unfitness;—still I hesitate, as I am about to assume the obligations which have been so well and so ably discharged by those of my fellow members who have, with so much honor and dignity, filled this place.

To my friends around me I look for aid and counsel, for the right and impartial discharge of the duties devolving upon me; and to you, Gentlemen of the Association, I must appeal for that kind forbearance which may serve in some degree to render my duties less onerous, and my failures less embarrassing.

We have again met together after the usual interval, to compare the results of our labors in the service of Truth,—for Science is only another expression for the *true* in the Universe. We have come not only from all parts of the United States, but I see around me others who dwell amid different social and political surroundings. But here we all meet upon common ground, and with a common object in view.

Science recognizes no artificial boundaries,—the heavens present no civil or political divisions,—nor do the formations of the earth on which we stand recognize the limits of states or countries.

Is it strange, then, that we should forget artificial distinctions and divisions, in the pursuit of the great objects in which we are engaged,—each one viewing the labor of his fellows with that generous spirit which places it in its true position in the scale of merit.

We come together not to proclaim dogmas but to contribute our atoms of truth to the great fabric of Science. We have all gone back to the manifestations of the great Creator of the Universe for the study of those truths and those laws which were conceived by *one mind* and impressed by *one will* upon all created things.

The scintillations from yonder heavens, and the scarcely less brilliant gems of earth, tried by the laws of physics and of chemistry, will be displayed before us. The development of vitality and the problem

of life, in its past and its present phases, will not be the least interesting exhibition of our labors, and all these are to be woven together in one harmonious whole, to constitute our Science.

The title of our Association distinctly proclaims its objects. It is for the *advancement* of Science, and not for its diffusion, that we meet. It is in the hope of communicating new truths, and of adding something to the common stock of knowledge that we have associated ourselves.

To those, therefore, who are not of us, but who, nevertheless, honor us with their countenance and presence, we may excuse ourselves for making no popular display, and for discussing questions purely in their scientific relations.

But it is not to be understood from this, that our labors have no relation to the requirements of the active world around us; — scarcely an intelligent person, but must feel that Science has done much for human advancement.

It is no degradation to Science to put her hand to the plough, the loom, and the anvil, to speed the traveller on his way at such a rate that the term *travelling* will soon become obsolete, and to convey intelligence from man to man over wide distances even in advance of time itself.

All this and much more, which this occasion will not allow me to speak of, has Science done for practical life; — and in all this she has advanced civilization, — has promoted the comforts, the happiness, and well-being of mankind. Is she not, therefore, as a handmaid, worthy of your consideration, worthy of being recognized and inquired of by the recipients of her bounty, whether her convenience or welfare may not be promoted in some degree or in some manner, that she may the more rapidly advance those great objects and interests which lie at the foundation of modern civilization?

Before concluding I cannot forbear calling your attention to the circumstance that we are now assembled under the same roof where our Association in embryo first met, and where the true hearts and kindly spirits of some among our departed colleagues first held counsel upon the question, then momentous, whether American scientific men could be prevailed upon to unite in a harmonious confraternity for the advancement of their cause.

In yonder chamber, eighteen years ago, sat half a dozen men who

had just returned from the arduous field-labors of the year, and were comparing their observations one with another, and each one communicating freely new facts and new conclusions, for the harmonious working of the whole in a single science. This labor over, the question of inviting other laborers, in the same field of science, to join them in similar interchange of views, facts, and results, was discussed; on the one hand with sanguine hope, and on the other with timid doubt.

A second year the same parties were assembled in the same room, and around the same table, when the subject was again discussed, and what had before appeared desirable now seemed a pressing necessity, and it was decided to take some action.

The youngest member of that group, who felt himself too inexperienced to take any prominent part in these discussions, stands before you to advocate, not his own, but the merits of his colleagues; and, though the birth of the Association was proclaimed in a sister city, we claim for our own city the inception of the *Association of American Geologists*, of which our present *Association for the Advancement of Science* is the legitimate heir.

Gentlemen, again asking your attention not so much to the strict letter as to the spirit of our Constitution, I shall announce that our assembly is organized for the transaction of business.

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At the conclusion of the President's address, the Hon. Amasa J. Parker, in behalf of the Local Committee and the citizens of Albany, welcomed the members of the Association in these words:—

MR. PRESIDENT AND GENTLEMEN OF THE ASSOCIATION:— As a member of the Local Committee, the agreeable duty has been devolved upon me of welcoming you, at this tenth annual meeting of the Association, to our State and city. We recur with pleasure to the fact that this is the second time we have been honored by your presence within the last five years; and we trust our city may be found so desirable a point for the sittings of the Association, with reference to its locality, its public institutions, the love of science, and the energetic devotion of many here to its interests, as to lead to its selection frequently hereafter as the place of meeting. We shall

always stand ready to extend to all its members and to all who are attracted to its meetings, as we now do, a most cordial welcome.

The hopes of science in this country centre in this Association. It embraces the most learned men, not only of our own country, but of the whole American continent. We are proud of the reputations of our men of science, already commanding the respect and admiration of the Old World. Who is not proud of the reputations of Henry, Silliman, Hall, and Bache? Who does not rejoice that the love of science of the great Franklin is continued in his descendants? Who is not proud of Peirce, Mitchel, and Dana, and the many others who are by no means to be considered as forgotten on an occasion like this because not specially named? Who does not rejoice that Agassiz, the great European Naturalist, was attracted to make our country his residence, as well by the congeniality of his associates here, as by the wide field afforded for scientific exploration?

We claim with pride our full share in the great scientific discoveries of the age. But we must never forget that science has no country, — that it is limited only by the Universe of God, — that it is but the development of truth which pervades all the works of the Creator, revealed to its votaries in proportion to the merit with which it is pursued, rewarding with its attainment, not only those who seek for knowledge for the intrinsic pleasure its acquisition affords, but blessing, in some form, the whole human race, by its benign aid to the advancement of agriculture, commerce, and manufactures. Science thus rewards all, by affording to some the highest mental enjoyment, and to others a vast increase of physical comforts.

In the spirit of this universality of science, and in the hope of promoting more extensively the objects of this Association, an effort was made to secure the attendance at this meeting, of many of the learned men of Europe. A general printed circular was addressed to the European *savans* last winter, from the Association; but the invitations from the Local Committee were not sent till June, in consequence of the delay incident to the correspondence with ship-owners and agents on both sides of the Atlantic. The owners of ocean steamers and packet ships promptly and most generously responded to the request of the Local Committee. More than thirty-five passages across the Atlantic both ways were placed at our disposal. These free passages were tendered only to those most eminent in science. Such men

could hardly be expected to leave their important positions and trusts on so short a notice. They all responded to our invitations most gratefully, and expressed an earnest desire to visit this country, and to attend upon the present occasion. It was expected, indeed, until very recently, that several distinguished foreigners would have honored us by their presence; but from various reasons they have been obliged reluctantly to decline. Liebig, for whose attendance Mr. Wadsworth had made so generous a provision, was compelled to decline the invitation on account of illness in his family. The meeting of the British Association for the Advancement of Science is at this time about being held, and doubtless prevented many of the learned men of England from attending here.

The Local Committee avail themselves of this occasion to express the great obligation they feel to the ship-owners and mercantile marine of the country for the great liberality they have evinced in promoting the objects of the present meeting in the manner before stated.

The Local Committee had thought it best to avail themselves of the presence of the Association to inaugurate two institutions; — the State Geological Hall and the Dudley Observatory. They had hoped that the vast geological collection of the State, for which we are so much indebted to your President, Professor Hall, would have been arranged and placed in the new building erected by the State for that purpose, in time for the present meeting; but the abrupt adjournment of the Legislature, without passing the supply bill, has prevented its completion and delayed the arrangement of the specimens. Meantime large additions to these collections are being made by the curator, Colonel Jewett, who is now in the field for that purpose.

The new instruments for the Dudley Observatory have been delayed, from unavoidable causes, much longer than was anticipated. The great Meridian Circle, now nearly finished at Berlin, will be here and mounted in a few weeks. The Transit Instrument is now finished and on its way. Both of these were, by the contract made by Dr. Gould, to have been delivered before the first of this month. The delay of the former was occasioned by a defect in the first casting of the axis.

The Observatory building has required enlarging for the reception of an instrument of so much larger size than was at first contemplated. The clocks, chronographs, barometers, thermometers, and magnetic apparatus have all been received, and will be open to your inspection.

The clocks, to give us time here during our meetings, are regulated by the instruments in the Observatory, and, when all our arrangements are perfected, will give time, if required, to all the railroads diverging from this city. The magnetic current from yonder hill can tick the time, correct to the tenth of a second, at Boston, Montreal, St. Louis, and New Orleans. Science shall thus point the way to secure to the works of man something of that system and order which pervade the works of God, and, in contributing largely to the business facilities of the age, shall lessen greatly the hazards of human life.

We acknowledge the great obligations which science and its votaries owe to the public press, and I am desired, in conclusion, for the purpose of securing accuracy in the published accounts of the proceedings of this Association, to request that the reporters who may attend the meetings from day to day, will submit their reports for correction to those who have taken part in the proceedings, before sending them to press. In no public proceedings can accuracy be more desirable, and more difficult to be secured by a spectator, than in matters of science.

In repeating the cordial greeting with which I am charged, I beg leave to assure the members of the Association of the pleasure their presence affords to our citizens, and of the sincere wish of the latter, that the visit of the former to our city may be made as agreeable to themselves as it will be useful to the great cause to which it will be devoted.

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The Annual Address was not delivered by the retiring President, Professor Torrey, as he was unable to attend the meeting.

A Report on the Present State of our Knowledge of Linguistic Ethnology was read on Monday afternoon, August 25.

No lengthened abstract of the proceedings, scientific and executive, of the Albany Meeting of the Association is necessary in this place, as they are contained in full in the papers and resolutions printed in this volume.

The officers elected for the next meeting are Professor J. W. BAILEY, of West Point, President; Professor JOHN LECONTE, of Columbia, S. C., General Secretary; and Dr. A. L. ELWYN, of Philadelphia, Treasurer. The Permanent Secretary, Professor JOSEPH LOVERING, of Cambridge, was elected for a second term.

The Association voted to hold their next meeting at Montreal, Canada, on Wednesday, the 12th of August, 1857, having received an invitation to visit that city from prominent citizens.

During the session of the Association, the members and their ladies, besides receiving many private hospitalities, were elegantly entertained on Thursday evening, August 21, at the capitol, when the rooms of the State Library, which are connected with the capitol by a corridor, were thrown open to the inspection and enjoyment of the members; on Friday evening by Robert Townsend, Esq.; on Saturday evening by John V. L. Pruyn, Esq.; on Monday evening, in the new Geological Hall; on Tuesday afternoon by the venerable Mrs. Blandina Dudley, and on Tuesday evening by Hon. Franklin Townsend; on Wednesday evening, August 27, by Stephen Van Rensselaer, Esq., and on Thursday evening, August 28, by Edward C. Delevan, Esq.

Through the kindness and unwearied exertions of the Local Committee and other citizens of Albany, the Association received, individually and collectively, many attentions, and took pride and pleasure in acknowledging the same, as far as was in their power, by the votes of thanks which were unanimously passed at the close of the meeting, and which are printed in this volume.

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During the meeting, a delegation consisting of Professors John W. Dawson and C. C. Smallwood, Rev. J. Flanagan, Dr. Thomas W. Jones, A. N. Rennie, Esq., Sir William E. Logan, H. Barnston, Esq., and Dr. Slingston, appeared as a delegation from Canada, and presented an invitation, in behalf of the city of Montreal and the Natural History Society of that city, to the Association to hold its next meeting in Montreal.

Dr. Steiner offered an invitation in behalf of the Maryland Institute and citizens of Baltimore, that the Association should hold its next meeting in that city.

The following invitation was also received from Springfield: —

*Commonwealth of Massachusetts. City of Springfield. In the year one thousand eight hundred and fifty-six.*

*Resolved*, That the City Council of the city of Springfield, hereby

tender to the American Association for the Advancement of Science, the use of the City Hall and other public rooms; and respectfully invite them to hold their next annual meeting in Springfield.

*Resolved*, That the City Clerk forward to said Association now in session at Albany an attested copy of these resolutions.

In Board of Aldermen, August 22, 1856. Read, passed, and sent down. JOSEPH INGRAHAM, Clerk.

Common Council, August 25, 1856. Read and passed.
C. C. CHAPIN, Clerk.

A true copy. Also, a true copy of record.
Attest. JOSEPH INGRAHAM,
City Clerk of Springfield, Mass.

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## RESOLUTIONS ADOPTED.

*Resolved*, That the Sectional Committee be held responsible for the character of the communications admitted, and for that of those authorized to be published in the Proceedings.

*Resolved*, That the Chairman of the Sections be requested to notify members that strict adherence is expected to the time named for the reading of their papers, and that they be requested to close the communications at the expiration of the time so specified.

*Resolved*, That the time occupied in the discussion of any paper shall not, unless by a special vote of the Section, exceed one half of the time allowed for the reading of the paper.

*Resolved*, That the limit of time allowed to papers, entered without specification of the time required, be twenty minutes.

*Resolved*, That Dr. Blotchford, the representative of the American Medical Association, as a substitute for Dr. Pitcher, be presented to the Association for the Advancement of Science.

*Resolved*, That a delegation be appointed to represent this Association in the West at the next meeting of the American Medical Association.

*Resolved*, That for the remainder of the present session, the provisions of the old Constitution be continued in force, and that the Revised Constitution go into effect at the opening of the next meeting.

*Resolved*, That the Vice-President for the next meeting be appointed at the present meeting, according to the forms of the old constitution as applied to the other General Officers.

*Resolved*, That Professor Haldeman's Report be printed, and two hundred and fifty copies placed at his disposal; and that he be requested to continue his researches in Linguistic Ethnology, with a view to report a system of notation for American and exotic Languages.

*Resolved*, That the papers read at this meeting be referred to the Standing Committee, to determine in reference to their publication, and that the papers not accepted for publication be returned to their authors.

*Resolved*, That the Permanent Secretary be allowed to put the Proceedings of the Albany meeting to press one month after the adjournment of the Association, and that one thousand five hundred copies be printed.

*Resolved*, That the Standing Committee be authorized to extend an invitation to Foreign Learned Societies to attend the Annual Meetings of the Association.

*Resolved*, That volume nine of Proceedings be presented to the State Library of New York; that volumes six, seven, eight, nine, and ten, be presented to the Athenæum of Nantucket, and the tenth volume to those gentlemen of Albany, not members, who have contributed to the funds of the Association; and volumes seven, eight, and nine to Mr. Horton, in consideration of his services as Assistant Local Secretary.

A request from P. J. O. Chauveau, Superintendent of Education for Lower Canada, that two copies of the Proceedings be furnished him, one for the Normal School, and the other for the Library of Superintendence, was referred to the Permanent Secretary, with power to give such volumes as were not scarce.

*Resolved*, That the Standing Committee be authorized to act for the Association in any matters of business which may not have been completed at the time of the adjournment of the Albany meeting.

*Resolved*, That the salary of the Permanent Secretary be increased to $500 a year.

*Resolved*, That the use of the Hall be granted to Dr. Hare, after the adjournment of the Association.

*Resolved,* That whereas the American Association for the Advancement of Science regard the full and thorough geological survey of the State of Ohio as highly important in a scientific, as well as economic point of view, the following persons be appointed a Committee to memorialize the Legislature of that State during its session in the coming winter, to make a just and liberal appropriation to carry forward the work of such geological survey. [This committee is printed in the first part of the volume, p. viii.]

*Resolved,* That a Special Committee of five be appointed to investigate the principles which render precious metals current, as moneys,— to promote the establishment of a simple and uniform system in the Mints of the United States,—and to invite a general conformity in the coinage standards of other nations. [Referred to the Committee on Weights, Measures, and Coinage.]

Professor C. Dewey remarked: "Some of you are familiar with the famous fir-trees of California, the *Abils Donglassei.* These trees, some of which are thirty feet in diameter, are supposed to be upwards of three thousand years old. The attention of the Association is called to the fact that these trees are being exterminated as the settlement of the country advances. But twenty-five of them, we are informed, are now left standing in the States, and they are not to be found but in one place. It is believed that an expression of interest in their preservation by the Association, made in the right quarter, would save the residue of these gigantic inhabitants of our primitive forests from destruction."

*Resolved,* That this matter be referred to Professor Henry, of the Smithsonian Institution, with the request that he will correspond, in behalf of this Association, with the authorities of California or at Washington, in relation to the preservation of these trees; or take such other course as may seem more effective.

The following resolutions were adopted in relation to the letter of Mayor Wood of New York, concerning a University in that city:—

*Resolved,* That the Advancement of Science, which forms the great object of this Association, requires also the establishment of Universities, where all branches of human knowledge may be pursued, under eminent Professors, to their last development.

*Resolved,* That the establishment of at least one such institution in any part of our country at the present time is an object of the highest

interest to this Association, and would, in their judgment, form an epoch in the progress of science in this country.

*Resolved*, That every judicious effort made for the accomplishment of this great work will receive our hearty commendation and firm support.

*Resolved*, That we consider the recommendation before us as such an effort as is referred to in the last resolution.

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## VOTES OF THANKS.

*Resolved*, That the Association returns its thanks to the Maryland Institute, who have so kindly invited us to assemble in their city, and expresses the hope that in some future year the Association may be able to meet their wishes.

*Resolved*, That the Association returns its thanks to the Mayor and Council of Springfield, for their invitation to meet in their city, and regret that they cannot accept it for the next summer.

*Resolved*, That the thanks of the Association be tendered to Professor Hall and Mr. Palmer, who have so kindly opened their collection for the inspection of members.

*Resolved*, That the heartiest thanks are due by the Association, and by every member of it, to the Local Committee for their admirable arrangements for the meeting, and their unremitting and most kind attentions during the progress of the session.

*Resolved*, That the thanks of the Association be tendered to the Directors of these railroads: New York Central; Michigan Central; Western; Hartford and New Haven; Baltimore and Ohio; Pennsylvania; Philadelphia, Wilmington, and Baltimore, and of the steamer Alida, and the steamships from New York to New Orleans, for the free return tickets which have been offered to members in attendance at this meeting.

*Resolved*, That the thanks of the American Association be presented to the Directors of the Cunard line of steam-packets, and especially to Mr. Edward Cunard, for the very prompt and generous manner in which the free passages were tendered by these lines for scientific gentlemen from Europe who might desire to attend this meeting; and that

similar thanks be offered to the Directors of the Bremen line, of the Glasgow Steamship Company, of the Collins line, and of the Belgian line, for similar acts of generosity.

*Resolved*, That thanks be returned to Messrs. E. C. Morgan, Mortimer Livingston, Cornelius Grinnell, Spofford, Tileston & Co., and Grinnell, Minturn & Co., for the generous offer of free passages in the sailing packets belonging to them.

*Resolved*, That, in the words of a distinguished foreigner to the Local Committee, such acts exalt the commerce of America, and place it at the head of the commerce of the civilized world.

*Resolved*, That the thanks of the Association be tendered to the Trustees or Directors of the State Library; Dudley Observatory; Albany Academy and Institute; Medical College; Albany Hospital; Geological Hall, Agricultural Rooms, and Collections; New York State Agricultural Society; Female Academy; Penitentiary; Albany Rural Cemetery, for the invitations which have been extended to its members, and the many facilities offered for inspection.

*Resolved*, That the sincere thanks of the Association be returned to the Legislature of New York and the Trustees of the Capitol, for the ample accommodations which have been afforded for the meeting of the Association, its Secretaries, and Committees.

*Resolved*, That the thanks of the Association be presented to the President of the Mechanics and Farmers Bank for his generosity in negotiating the funds of the Association.

*Resolved*, That our very warm thanks are returned to the citizens and ladies of Albany, who have, with such unbounded hospitality, opened their hearts and dwellings to the reception of the members of the Association during this meeting, and that our best wishes attend them now and will remain with them through our lives.

The following remarks were made by Rev. Dr. Ferris: —

The interval since this Association met last in this city is short, and yet, on our assembling, we find not among us the genial friend — the ripe scholar — the true man — the man of science, Dr. T. Romeyn Beck. It has pleased an allwise Providence that he should be carried to the house appointed for all the living. It was my privilege to know well four of the Becks — brothers.

The Adjutant-General, Nicholas, passed away many years since, ere he had accomplished what an earnest mind promised. All know how Dr. John B. Beck graced the medical profession, and won for himself universal respect and admiration as a Professor in the College of Surgeons and Physicians of New York; of Dr. Lewis C. Beck the State of New York has an abiding memento in the results of the Scientific Survey of the State, as will be seen in the collections of the State cabinet. His works on Chemistry and Botany have been the guides of many an inquirer, and his labors in his favorite department in Rutgers College will never be forgotten.

Dr. T. Romeyn Beck, — as a most successful educator — as an indefatigable laborer in various branches of learning — as the author of the first American work on Medical Jurisprudence (I think), which has become a standard in that department, and been translated and used abroad, and as a Professor of a Medical Institute for many years, — has occupied a place granted to very few. He became, in 1817, the Principal of the Boys' Academy, whose edifice you have all admired in the Park opposite, an institution which received new life under his energy, and which has yielded to the various walks of life a very large number of most able men, and where (I believe I do not mistake), in connection with Dr. Beck, our esteemed associate of the Smithsonian, whose reputation is world wide, received his first impulse in those researches which have so distinguished him. Here Dr. Beck continued for over twenty years; and, while here engaged, was conducting special chemical instruction, and was lecturer in the Medical College then at Fairfield. He was the most industrious man in scientific labors I have known, — apparently never tiring, and never confused by the number or variety of his pursuits. He was eminently a man of system, and to this must be attributed his ability to accomplish so much. One of the choicest heirlooms must have been his volumes of Common Places, the gatherings of a most laborious life. In all enterprises undertaken here for science or literature, his was an active part. The circle of his friends was large, and among educated men especially. His latter years were occupied as Secretary of the Regents of the University of the State of New York — a most important and responsible office — and in the prosecution of science. He has by no means lived in vain. Having reached a full measure of years, he has gone

to his rest; but his memorial is in many hearts. Albany city and New York State have reason to note it in imperishable record, that he was theirs.

We love to trace influences to their sources, to inquire whence all this? It is enough to say that this quartette of brothers had a mother worthy a place above hers of the Gracchi. Think of her, as when, advanced beyond the common lot of life, she was coadjutor and reliance in the meteorological observations taken at the Albany Academy for many years.

Mr. President, — As our friend has gone, so we are going; this may be the last meeting to some of us; — may ours be a full preparation for it, such a preparation as true religion secures.

I beg to offer the following resolutions: —

*Resolved*, That this Association record, with feelings of regret, the removal by death of T. Romeyn Beck, M. D., L L. D., of the city of Albany, since its last meeting in this place.

*Resolved*, That the scholar-like attainments of our associate in various departments of Science and Literature, and his long and successful devotion to the interests of learning, his distinguished ability and his profound worth have given him a high place among the sons of Science, and the benefactors of man; and the memory of such should be fondly cherished.

## REPORT OF THE PERMANENT SECRETARY.*

The duties of the Permanent Secretary during the last year have been nearly doubled in consequence of the re-publication of the Cleveland volume, the charge of which was committed to his hands. The preparation of the Proceedings of the Cleveland and Providence meetings for the press, the examination of proof-sheets, the distribution of the volumes when printed, and the making of contracts and payment of bills connected with these matters, constitute the most onerous part of the labor performed by the Permanent Secretary. The Cleveland and Providence volumes were published in April, and have been, as far as practicable, distributed to members entitled to receive them. Also circulars have been sent as follows: —

1st, To newly elected members.

2d, To members, calling on them for papers to be printed.

3d, To members, informing them that the volumes of Proceedings were ready.

4th, To members, informing them that volumes had been sent.

5th, To delinquent members.

6th, To members who have paid assessments and wish receipts.

Since August 25, 1855, when the Permanent Secretary made his last Report, down to August 20, 1856, the date of the present report, $960.50 have been collected by the Permanent Secretary, mostly in the form of assessments, but partly by the sale of the Proceedings of the Association. If to the above-named sum are added $291.92, received from members directly by the Treasurer, and $1,186.54 received by the Treasurer from members through the Permanent Secretary, an aggregate collection of $2,438.92 results. The Permanent Secretary has also received a balance of $333, subscribed at Provi-

* In the Providence volume, page 298, line 7, instead of "eighty-six dollars," read seventy-six, which corresponds with the statement on the preceding page of the same volume, 5th line from bottom. On line 8 of same page, for "thirty dollars," read twenty dollars. On line 11 of same page, for "eight hundred and seventeen dollars," read seven hundred and ninety-seven dollars. On page 299, lines 21 and 22, for "sixty-eight dollars and thirty-three cents," read forty dollars and sixty-eight cents. These numerical errors exist only in the *printed* Reports, and the numbers, as corrected, correspond to the manuscript Reports.

dence, from the Local Committee of that city, to assist in the publication of the Proceedings of the Providence meeting, and from G. P. Putnam & Co. $11.29, for the sale of Proceedings. The grand total amounts to $2,783.21.

The expenses since the last account rendered (which is printed in the volume of Proceedings at Providence, pages 304 and 305), have amounted to $2,647.69. This sum exceeds the average annual expenses by about $1,000. The excess has been caused by the reprint of the volume of Cleveland Proceedings. The total expenditure of $2,647.69 may be divided as follows: —

| | |
|---|---|
| For the preparation and publication of vols. VII. and IX. | $2,201 00 |
| Salary of Permanent Secretary | 300 00 |
| Postage | 45 80 |
| Printing and sending of circulars | 25 72 |
| Sundries | 70 67 |
| Discount on distant banks | 4 50 |
| Total | $2,647 69 |

If the expenses (or $2,647.69) are subtracted from the income of the Association (or $2,783.21), we have a balance above expenditure, of $135.52. This is to be added to the balance of last year, which was $111.96 in the hands of the Permanent Secretary, and $620.58 in the hands of the Treasurer. The present balance is $868.06, of which $106.31 is in the hands of the Permanent Secretary, and $761.77 in the hands of the Treasurer.

The Permanent Secretary states that, in conformity with the enactments of the Association, and the notice given by him last year to the Standing Committee, he has struck from the list of names those, and those only, from whom no dues have been received since the last Albany Meeting, in 1851. Whereas 91 new members were added at Providence, 492 have been struck out since that meeting, the number of members being reduced from 1,023, as before the Providence Meeting, to 622, as at the beginning of this meeting. As each person so struck from the list of members is now indebted to the Association for $12, this repudiation of assessments makes a loss of funds to the Association, of $5,904.

It should be added that several of those struck out have since paid the $12 due, and will be restored to their places in the next volume.

## REPORT OF THE AUDITORS.

We have examined the accounts of the Treasurer and Permanent Secretary, and find them correct; and the balances in their hands to the credit of the Association stated in the preceding Report of the Permanent Secretary, to wit:—

| | |
|---|---|
| In the hands of the Permanent Secretary, . . . . | $106.31 |
| " " " Treasurer, . . . . . . | 790.20 |
| | $896.51 |

Signed JOHN L. LECONTE, J. H. C. COFFIN, } *Auditors.*

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*American Institutions receiving Copies of the Proceedings of the American Association, by Vote of the Association.*

| | Volumes VII. | VIII. | IX. |
|---|---|---|---|
| American Academy, *Boston,* . . . . . . . | " | | " |
| Natural History Society, *Boston,* . . . . . . | " | | " |
| New York Lyceum, *New York,* . . . . . . | | " | |
| Philadelphia Academy of Natural Sciences, *Philadelphia,* | " | " | " |
| American Philosophical Society, . . . . . | " | " | " |
| Western Academy of Natural Sciences, *Cincinnati,* . | " | | " |
| Cleveland Academy of Natural Sciences, *Cleveland,* . | " | " | " |
| Smithsonian Institution, *Washington,* . . . . . | " | | " |

*List of European Institutions to which Copies of the Proceedings of the American Association were distributed by the Permanent Secretary in* 1856.

| | Volumes. | | | | |
|---|---|---|---|---|---|
| | II. | IV. | VII. | VIII. | IX. |
| *Stockholm*, — Kongliga Svenska Vetenskaps Akademien, . . . . . . . | | | * | * | * |
| *Copenhagen*, — Kongel. danske Vidensk. Selskab, . . . . . . . | | | * | * | * |
| *Moscow*, — Soc. Imp. des Naturalistes, . | | | * | * | * |
| *St. Petersburg*, — Acad. Imp. des Sciences, | | | * | * | * |
| " " Kais. Russ. Min. Gesellsch., | | | * | * | * |
| *Amsterdam*, — Acad. Royale des Sciences, . | | | * | * | * |
| *Haarlem*, — Holl. Maatschappij der Wettenschappen, . . . . . . . . . | * | | * | * | * |
| *Berlin*, — K. P. Akad. der Wiss., . . | | | * | * | * |
| *Breslau*, — K. L. C. Akad. der Naturf., . | | | * | * | * |
| *Franckfurt*, — Senckenbergische Gesellschaft, | | | * | * | * |
| *Göttingen*, — Königl. Gesellschaft der Wiss., | | | * | * | * |
| *Munich*, — K. B. Akad. der Wiss., . . | | | * | * | * |
| *Prag*, — K. Böhm. Gesellschaft der Wiss., | | | * | * | * |
| *Vienna*, — K. Akad. der Wiss., . . . . | | * | * | * | * |
| *Bern*, — Allg. Schw. Gesellschaft, . . | | | * | * | * |
| *Geneve*, — Soc. de Physique et d'Hist. Nat., | | | * | * | * |
| *Bruxelles*, — Acad. Royale des Sciences, . | | | * | * | * |
| *Liège*, — Soc. Royale des Sciences, . . | | | * | * | * |
| *Paris*, — Institut de France, . . . | | | * | * | * |
| *Turin*, — Accademia Reale delle Scienze, | | | * | * | * |
| *Madrid*, — Real Acad. des Ciencias, . . | | | * | * | * |
| *Cambridge*, — Camb. Philosophical Society, | | | * | * | * |
| *Dublin*, — Royal Irish Academy, . . | | | * | * | * |
| *Edinburgh*, — Royal Society, . . . . | | | * | * | * |
| *London*, — Board of Admiralty, . . | | | * | * | * |
| " East India Company, . . | | | * | * | * |
| " Museum of Practical Geology, | | | * | * | * |
| " Royal Society, . . . . . | | | * | * | * |
| | 1 | 1 | 28 | 28 | 28 |

## CASH ACCOUNT OF THE

Dr. AMERICAN ASSOCIATION in

| | |
|---|---|
| Metcalf & Co., Printers, | $8.00 |
| Expenses at Providence, | 50.00 |
| Brainerd & Burridge, for rejected map in VIIth volume, | 37.50 |
| Metcalf & Co., for printing blank bills, | 5.67 |
| Assistant local secretaries at Providence, | 15.00 |
| Rice & Kendall, for paper, | 579.52 |
| Binding volume of Washington Proceedings, | 158.25 |
| Metcalf & Co., for printing VIIth and IXth volumes, | 890.98 |
| Lemon, for binding VIIth and IXth volumes, | 159.82 |
| Duval, for printing plates, | 99.00 |
| Bradford, for printing and engraving plates, | 63.00 |
| Bien, for printing plates, | 100.00 |
| Moore & Crosby, for printing plate, | 20.00 |
| Kilburn & Mallory, for wood-cuts, | 30.00 |
| Index for Cleveland and Providence volumes, | 10.00 |
| Binding extra copies of Addresses of Dana and Gibbs, | 4.06 |
| Circulars to delinquents, etc. etc., | 20.00 |
| Engraved circular to eminent foreigners, | 5.72 |
| William Mills, services in distributing volumes, | 18.37 |
| Express, | 22.50 |
| Postage, | 45.80 |
| Discount on distant banks, | 4.50 |
| Salary of Permanent Secretary, | 300.00 |
| | $2,647.69 |
| Balance to next account, | 106.31 |
| | $2,754.00 |

## PERMANENT SECRETARY.

| *Account with* JOSEPH LOVERING. | Cr. |
|---|---|
| Balance from last account, . . . . . . . . . | $111.96 |
| Salary of Permanent Secretary, . . . . . . | 300.00 |
| Cash from Treasurer, . . . . . . . . . . | 1037.25 |
| Cash from Local Committee at Providence, . . . . | 333.00 |
| G. P. Putnam & Co. sale of Proceedings, . . . . . | 11.29 |
| Assessments from August 21, 1855, to August 20, 1856, . | 960.50 |
| | $2,754.00 |

We certify that we have examined the preceding account of the Permanent Secretary, comparing the credits with the Treasurer's account, and the receipt book, and the debits with the several vouchers, and find the whole correct; and the balance of one hundred and six dollars and thirty one cents, properly credited in the next account.

JOHN L. LECONTE, } *Auditors.*
J. H. C. COFFIN, }

ALBANY, August 27, 1856.

## STOCK ACCOUNT OF THE PERMANENT SECRETARY.

*Volumes Distributed or Sold.*

| Volumes | I. | II. | III. | IV. | V. | VI. | VII. | VIII | IX. |
|---|---|---|---|---|---|---|---|---|---|
| DELIVERED TO | | | | | | | | | |
| J. Y. Smith,* . . . . | * | * | * | * | * | * | * | * | |
| E. H. Barton,* . . . | * | * | * | * | * | * | * | * | |
| G. W. Dean,* . . . . | | | | | * | * | * | * | * |
| B. Stanard,* . . . . | * | * | * | * | * | * | | | |
| M. L. Clark,* . . . . | * | * | * | * | * | * | | | |
| J. B. Cherriman,* . . . | * | * | * | * | * | * | * | * | |
| S. H. Douglass,* . . . | * | * | * | * | * | * | * | * | |
| J. Pennington,* . . . | * | * | * | * | * | * | * | * | * |
| P. J. O. Chauveau,*† . | * | * | * | 2 | 2 | 2 | 2 | 2 | 2 |
| J. Edmondson,* . . . | * | * | * | * | * | * | * | * | * |
| F. Taylor,* . . . . | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| J. S. Harrequi,* . . . | * | * | * | * | * | * | * | * | * |
| Providence Athenæum,† . | * | * | * | * | * | * | * | * | * |
| New York Historical Society, . . . . . | | | * | * | * | * | * | * | * |
| Philosophical Society at Philadelphia, . . | * | * | * | | * | | | * | * |
| D. Treadwell, . . . | | | | | | | | | * |
| J. C. Delano, . . . . | | | | | * | * | | | |
| W. D. Henkle,* . . . | | | | | | | * | | * |
| J. G. Anthony, . . . . | | | | | | * | | | |
| Amos Binney, . . . | | | | | | * | | | |
| J. B. Lindsley,* . . . | | | | | * | * | | | |
| J. B. Paine,† . . . . | | | | | | | | | * |
| F. Paine,† . . . . . | | | | | | | | | * |
| T. Caswell,† . . . . | | | | | | | | | * |
| J. W. Dawson,* . . . . | | | | | | | * | * | * |
| T. D. Robertson,* . . . | | | | | | | * | * | * |
| C. F. Benedict,* . . . | | | | | | | * | * | * |
| —— Bidwell*, . . . | | | | | | | | | * |
| A. Sager,* . . . . . | | | | | * | | | | |
| Brown University,† . . | | | | | | | * | | * |
| N. Y. State Library,† . | | | | | | | * | | * |
| Boston Athenæum, . . . | | | | | | | * | | * |
| Harvard College, . . . | | | | | | | * | | * |
| Yale College, . . . . | | | | | | | * | * | * |
| Munroe & Co.,§ . . . . | 5 | | 5 | 5 | 7 | 7 | 7 | | 7 |
| Putnam & Co., . . . | | | | | | | 13 | | 14 |
| Members, . . . . . | | | | | | | 341 | 91 | 404 |
| Institutions,‡ . . . . | | 1 | | 1 | | | 35 | 32 | 35 |
| Total, . . . . . | 19 | 15 | 20 | 21 | 27 | 27 | 419 | 142 | 485 |

* Sold. † By order of the Association. ‡ See pages 246–7.

§ Fifteen of these volumes were purchased, and twenty-eight given in exchange.

## BALANCE OF STOCK.

| Volumes, | I. | II. | III. | IV. | V. | VI. | VII. | VIII | IX. |
|---|---|---|---|---|---|---|---|---|---|
| Balance, March 20, 1856, | 84 | 54 | 285 | 265 | 481 | 339 | | 1037 | |
| Received from Binders, . | | | | | | | 1000 | | 1500 |
| Received from Munroe & Co.,* . . . | | 28 | | | | | | | |
| Total, . . . . . | 84 | 82 | 285 | 265 | 481 | 339 | 1000 | 1037 | 1500 |
| Delivered to Members or sold, . . . . | 19 | 15 | 20 | 21 | 27 | 27 | 419 | 142 | 485 |
| Balance, March 20, 1857. | 65 | 67 | 265 | 244 | 454 | 312 | 581 | 895 | 1015 |

* In exchange for volumes less rare.

## Account of G. P. Putnam & Co., with the Association.

| Volumes on hand, | I. | II. | III. | IV. | V. | VI. | VII. | VIII | IX. | Value. |
|---|---|---|---|---|---|---|---|---|---|---|
| January 1, 1856, · | 19 | 19 | 19 | 68 | 10 | 157 | | 20 | | $374.38 |
| Received, July 31, | | | | | | | 13 | | 14 | 40.50 |
| Total, . . . . | 19 | 19 | 19 | 68 | 10 | 157 | 13 | 20 | 14 | $414.88 |
| January 1, 1857, . | 4 | 4 | 4 | 69 | 7 | 152 | 8 | 8 | 8 | 395.84 |
| Now due, for sold, | 15 | 15 | 15 | —1 | 3 | 5 | 5 | 12 | 6 | $19.04 |

*February*, 1857.

## REPORT OF THE TREASURER.

The Treasurer received at Providence from the Permanent Secretary, eleven hundred and ninety-seven dollars and fifty cents, collected by him from members. He has received himself from members, since his last report, two hundred and ninety-one dollars and ninety-two cents.

He has paid to the Permanent Secretary, his salary of three hundred dollars: to J. Bien, for Plates, sixty dollars; to Edward Wharter, thirty dollars and seventy-five cents; and to the Permanent Secretary, nine hundred and fifty-six dollars. These expenditures, amounting to thirteen hundred and forty-six dollars and seventy-five cents, taken from the receipts of fourteen hundred and eighty-nine dollars and forty-two cents, leave a balance of one hundred and forty-two dollars and sixty-seven cents, which, added to the balance of last year, (of six hundred and forty-nine dollars and three cents,) makes a total balance of seven hundred and ninety-one dollars and seventy cents.

A. L. Elwyn, *Treasurer.*

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## REPORT OF THE AUDITORS.

We have examined the preceding account of the Treasurer, comparing the debits with the account of the Permanent Secretary, and find a difference of $1.50 in favor of the Secretary; and with this correction, that the balance in the hands of the Treasurer to the credit of the Association should be $790.20 instead of $791.70.

No detailed accounts are presented of the money received from members, nor any prior statement of the balance on hand last year. We believe them, however, to be correct.

John L. LeConte, } *Auditors.*
J. H. C. Coffin, }

# CORRESPONDENCE.

November 1, 1855.

SIR, — We have the honor to inform you that the Tenth Meeting of the American Association for the Advancement of Science will be held in the city of Albany, commencing its sittings on Wednesday, August 20, 1856, and continuing during such time, not less than a week, as may be then decided.

It is anticipated that the Dudley Observatory and the Geological Museum will be inaugurated during the meeting, upon days to be set apart for the purpose, and it is also proposed that excursions be made to points of scientific and historical interest in the vicinity.

We are directed by the Association to solicit the honor of your presence on the occasion, and the Local Committee have instructed us to assure you of an earnest and cordial welcome. Permit us to hope that you will favor the Association by transmitting an affirmative reply to the General Secretary at Cambridge, Mass., or to the Local Committee at Albany, N. Y.

We have the honor to be, Sir, very respectfully yours,

JAMES HALL, *President.*
JOSEPH LOVERING, *Permanent Secretary.*
B. A. GOULD, JR., *General Secretary.*

T. ROMEYN BECK,
THOMAS W. OLCOTT,
JAMES H. ARMSBY,
*For the Local Committee.*

### *Past Meetings of the Association.*

| | | | |
|---|---|---|---|
| 1. Philadelphia, Pa., | 1848, | W. C. Redfield, | *President.* |
| 2. Cambridge, Mass., | 1849, | Joseph Henry, | " |
| 3. Charleston, S. C., | 1850, | " | " |
| 4. New Haven, Ct., | 1850, | A. D. Bache, | " |
| 5. Cincinnati, O., | 1851, | " | " |
| 6. Albany, N. Y., | 1851, | Louis Agassiz, | " |
| 7. Cleveland, O., | 1853, | Benjamin Peirce, | " |
| 8. Washington, D. C., | 1854, | James D. Dana, | " |
| 9. Providence, R. I., | 1855, | John Torrey, | " |

# INDEX.

# ERRATA.

## Part I.

Page 54, line 6 from bottom, *after* Liverpool *read* and Manchester.
" 55, in first table, *for* .024 *and* .088 *read* .025 *and* .090.
" 60, lines 10 and 20, *for* $\int$ *read* $\int_0^x$.
" 66, last line, *for* $d_{0|x}$ *read* $\delta_{0|x}$.
" 73, last line, *for* 1.803755 *read* $\bar{1}.803755$.
" 95, supply 12 as denominator in the last formula.

## Part II.

Page 33, line 1, *for* Cuchillo *read* Cuchilla.
" 39, " 33, " Altis " Celtis.
" 40, " 5, " cross " cropp.
" " " 34, " mosquito " moezquite.
" 42, " 12, " Lóbota " Cóbota.
" 44, " 3, " Liénagas " Ciénagas.
" " " 29, 38, &c., *for* Guehibabi *read* Juchibabi.
" 45, " 7, *for* di *read* del.
" " " 26, " Papaga " Papago.
" 47, " 6, " marshes " mashes.
" 49, " 29, " Pinajas " Tinajas.
" 50, lines 20 and 21, *for* is almost dry, and active to change, *read* is almost day and night busy to change.
" 74, line 33, *for the equation* $\frac{4 \times O S}{\overline{O P}}$ *read* $\frac{4 \times O S}{\sqrt{O P}}$.
" 177, " 21, *for* Retchporea *read* Retepora.
" " " 33, " aux saillant *read* aux angles saillants.

3 gal
174+